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How He Really Did It

THE WEB STRATEGY THAT TOOK AN OBSCURE SENATOR TO THE DOORS OF THE WHITE HOUSE

Plus: Obama's Geek Economist

Cheap Solar Power

p104

Jonathan Franzen Wants You to Hang Up

p88



The Authority on the Future of Technology October 2008

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49 The TR35

We present our eighth annual list of top innovators under 35. Of special note are Aimée Rose, winner of the Humanitarian of the Year award for her work in explosives detection, and JB Straubel, winner of the Innovator of the Year award for his work on the Tesla Roadster sports car. Other inventions include meditative video games, technology to prevent chip piracy, insect-like robots, and personalized vaccines.

■ www.technologyreview.com/tr35 Explore the TR35's research through videos, slide shows, and infographics.

78 How Obama Really Did It

Social technology helped bring him to the brink of the presidency.

By DAVID TALBOT

■ www.technologyreview.com/obama Watch an interview with the cofounder of Blue State Digital, the company behind Obama's Web success.

84 Obama's Geek Economist

Austan Goolsbee is a new breed of economic advisor for a new kind of presidential candidate.

By MARK WILLIAMS

ESSAY

88 "I Just Called to Say I Love You"

Cell phones, sentimentality, and the decline of public space.

By JONATHAN FRANZEN

7 Contributors

- 8 Letters
- 12 From the Editor

NOTEBOOKS

10 Managing Energy

We need to apply information technology to the energy grid. By Peter Corsell

10 Broadening Technology's Reach

Researchers should switch from the race for the best to bringing new technologies to the rest. By Johnny Lee

11 Battling Cellulose

Insights into biomass could improve biofuel production. *By Michelle Chang*

FORWARD

21 The Core of the Brain

A new mapping approach identifies the hub of the human cortex.

22 Flawless Vote Counts

Cryptography lets voters verify their ballots.

24 Broadband Anywhere

Sprint turns Baltimore into a giant wireless hot spot.

26 A Brief History of Microblogging

The popular startup Twitter and its competitors spawned an entire ecosystem.

28 Life Left in Light

Light microscopes make a comeback.

30 Solar Boom

New twists on the three leading solar technologies.

TO MARKET

33-36 Technology Commercialized

Liquid-lens webcam, artery drill, high-definition transmitter, gesture-controlled laptop, eBay for interest rates, first tidal power generator, glasses-free 3-D, 60-megapixel photography, more-sensitive mammograms, microRNA diagnostics.



Q&A

38 Mitch Kapor

The personal-computing pioneer says that the U.S. needs a CTO. By Kate Greene

www.technologyreview.com/ qanda See Mitch Kapor explain the benefits of a federal CTO.

PHOTO ESSAY

40 Where Cell Phones Go to Die

People are recycling more mobile phones each year. By Kate Greene



REVIEWS

96 "It's Not a Revolution if Nobody Loses"

A new age of "technological reproducibility" is here. *Ugh. By Emily Gould*

98 Personal Genomics: Access Denied?

Consumers have a right to their genomes. By Misha Angrist

100 Web App Writers: Rejoice, Beware

Google App Engine is easy to use and—at least initially—free. Is it too good to be true? By Erica Naone

HACK

102 Tesla Roadster

An electric sports car that generates buzz.

By Kevin Bullis

www.technologyreview.com/ hack Test-drive a Roadster with Tesla's JB Straubel.

DEMO

104 Intensifying the Sun

A new way to concentrate sunlight could make solar power competitive with fossil fuels. By Kevin Bullis

www.technologyreview.com/ demo See how the solar concentrators work.

FROM THE LABS

108 Nanotechnology109 Biotechnology110 Information Technology

34 YEARS AGO IN TR

112 Having the President's Ear

A look back at a time when science held sway. By Matt Mahoney

www.technologyreview.com/ advisors Browse a time line of science advisors to the president.





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DAVID TALBOT, in our cover story ("How Obama Really Did It," p. 78), reports that the Web has forever changed electoral politics-and one candidate was quicker to see this than others. "Barack Obama, more than Hillary Clinton and far more than John McCain, made newmedia platforms and his own social-networking site fulcra of his campaign," says Talbot, who found the backbone of the Obama camp's Web strategy in the Boston offices of Blue State Digital, the firm that manages the accounts of more than a million members of Obama's social network. "It seems that the ward heelers of another age-going door to door and driving old ladies to the polls-have been reincarnated as geeks who adapt server resources, send out targeted e-mail and textmessaging blasts, and chop up phone-bank lists for thousands of supporters to handle at their home computers."

Winner of the Overseas Press Club award for International Environmental Reporting, Talbot is *Technology Review*'s chief correspondent.

JONATHAN FRANZEN has written a funny, biting, intimate essay ("I Just Called to Say I Love You," p. 88) about our age's most cherished piece of personal technology: the cell phone.

"This piece grew out of a strange afternoon that I spent with my brothers in January on the occasion of my oldest brother's 60th birthday," says Franzen. "We were



all together in Oregon and took the opportunity to go through a bunch of boxes of our late parents' stuff. The most unsettling find was a slice of wedding cake, wrapped up in tissue paper and well preserved, from October 1944. But there was also a big cache of their early correspondence, much of it achingly personal. Writing this essay was my way of getting myself to sit down and read it. It was also, of course, my way of dealing with my rage against the cell phone."

Franzen is the author of three novels and two works of nonfiction. His novel *The Corrections* won the 2001 National Book Award.



EMILY GOULD draws parallels between Clay Shirky's celebration of social-networking technologies in his new book, Here Comes Everybody, and Walter Benjamin's warning—from the 1930s—of simulating reality through photography and film ("It's Not a Revolution if Nobody Loses," p. 96).

"At times of upheaval caused by technological change, critics have a responsibility to make us pay attention to what's happening, even -or especially-when changes are happening so quickly that we barely notice them, and mentioning them seems like stating the obvious," says Gould. "But while Shirky's right to marvel at the ways blogs, wikis, and social networks liberate us, I don't think he worries enough about the ways these technologies alienate us. In

looking at 'technological reproducibility,' Walter Benjamin had it right: he marveled *and* worried."

In a May New York Times Magazine cover story, Gould chronicled her exploits blogging for the gossip site Gawker. A book of her short stories will be published in 2010.

MISHA ANGRIST, an assistant professor at Duke University's Institute for Genome Sciences and Policy, writes about the health authorities' backlash against companies like 23andMe and Navigenics, which offer individuals analysis of their genetic information



("Personal Genomics: Access Denied?" p. 98). But as Angrist notes, it is far too late to begin denying people access to that information.

"I'm puzzled by the hysteria that these companies—and personal genomics in general—have provoked," he says. Angrist blogs at Genomeboy.com and has a book on personal genomics coming out next year.

GRIDLOCK

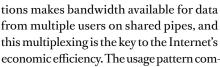
The problem discussed in your article "Internet Gridlock" (July/August 2008) is actually a side effect of a more profound

Technology

July/August '08

transition in patterns of network usage.

While the Internet is often touted as a "generalpurpose network" capable of supporting a wide range of innovative uses, in its present state it's actually a very uniform system tuned for short file transfers, like e-mail and Web browsingtransfers that are typically completed in less than one second each. The limited duration of these transac-



bines comfortably with the modest requirements of voice-over-Internet-protocol (VoIP) phone traffic, the most common exception to the paradigm of short file transfers.

> Using the Internet as the conduit for highdefinition video files is the game changer. The sheer size and popularity of these files challenges us to imagine more-complex traffic management systems. As a network engineer, I foresee that the Internet will certainly be required to manage more-persistent file transfer transactions in the future.

The most obvious way to approach this problem is with data stream classification and scheduling systems. Such

Classification and scheduling are routine parts of daily life, but their application to a system that has apparently worked well without them naturally arouses apprehension. Though change is often unsettling, it's the very essence of technical progress. Increased consumer awareness and higher standards of commercial disclosure are necessary to achieve moresophisticated Internet traffic management. Larry Hardesty's article is a constructive contribution to this process.

Richard Bennett Livermore, CA

WHO OWNS YOUR FRIENDS?

As an open-source advocate, I thought your article on how social-networking sites should incorporate data portability ("Who Owns Your Friends?" July/August 2008) touched on an important problem.



activities and relationships. This transition is going to be painful, both for the companies who derive value from monetizing the captive attention of their members and for the individuals who interact on a single network.

But the future demands this shift, and the welfare of the Web requires it. By incorporating decentralized technologies, social sites can help their members weather the coming changes.

Chris Messina San Francisco, CA

THE NEXT BUBBLE

I, too, was part of the Web bubble you discussed in the July/August "From the Editor" column ("The Next Bubble"). Though my company did well while the bubble was expanding, the prospect of making unrealistic amounts of money in short amounts of time quickly clouded our better judgment to sell holdings while the market was being

kind. I often refer to the original bubble days as "the Internet lottery," as the question of who succeeded or failed was often governed more by luck than by good business execution.

Some of the smartest people I know still seem to believe that it's possible to build vast wealth quickly on the basis of nothing but a working prototype for a service and the intangible promises of an Internet startup. But as most lottery winners prove, those who are unable to build value are usually unable to manage it as well.

Avi Weiss New York, NY

A NEW COLLIDER

I read with interest your articles related to experimental physics (May/June 2008). CERN's Large Hadron Collider (LHC) may cause the United States to relinquish its crown as the world's leader in physics. This is unfortunate, since the U.S. aban-

doned construction of its Superconducting Super Collider (SSC) in Texas in the early 1990s. It was to have had an underground ring circumference of 54 miles—more than three times the size of the LHC. The U.S. Congress canceled the SSC project in 1993, when its cost rose from \$4.4 billion to more than \$12 billion. While CERN searches for the Higgs particle, the U.S. is now left with a \$2 billion hole in Texas consisting of 14 miles of tunnel and 17 shafts to the surface.

Albert C. Costanzo Elkwood, VA

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NOTEBOOKS

Managing Energy

VE NEED TO APPLY INFORMATION TECHNOLOGY TO THE ENERGY GRID, SAYS PETER CORSELL.

WHETHER it is the price of oil, deteriorating environmental conditions, or the household electric bill, energy is affecting all of us more acutely these days. Demand for energy is rising worldwide, and that demand can no longer be met by simply building more power plants. With transmission and distribution systems overburdened and global warm-

ing threatening the environment, both utilities and consumers will have to pay closer attention to where, when, and how energy is generated and used.

Though acclaimed by the National Academy of Engineering as "the most significant engineer-

ing achievement of the 20th century," the electric power grid is outdated; it's a mechanically monitored, centrally managed system that has yet to take advantage of Internet-based information technology. If it did, and if it could integrate innovations such as solar panels, wind turbines, advanced batteries, and plug-in hybrid electric vehicles, the grid could be transformed into an intelligent, self-optimizing network. This "smart grid," which would deliver clean and efficient power, would be as consequential to the power industry as the Internet has been to the economy at large.

To illustrate the pressing need for a smart grid, consider a single emerging technology: plug-in hybrid electric vehicles. General Motors will release the Chevy Volt, the first such car scheduled to reach the market, in 2010. But a study by the Oak Ridge National Laboratory determined that 160 new power plants would be required if everyone plugged in such hybrids in the early evening, when electricity demand is already high. With smart grid technology, utilities could stagger charging times and offer consumers lower rates for off-peak electricity. This capability, dubbed "smart charging," would virtually eliminate the

> need for new power plants, according to the study.

The Electric Power Research Institute estimates that the poor reliability of the electric grid costs the U.S. economy \$100 billion today, but that a \$200 billion investment in the

smart grid would generate \$2 trillion in annual GDP by 2020. This will not happen overnight (nor did the Internet), but the investment is well worth it. Ultimately, the smart grid will dramatically transform the way we generate, consume, and think about energy-because it will make each one of us a relevant point on the grid.

The key to implementing a sustainable smart grid will be technology that scales to accommodate future energy needs, increases operational efficiency, and establishes a mutually beneficial relationship among utilities, consumers, and the environment, GridPoint (see page 58), a company I founded to advance energy efficiency technology, offers a comprehensive platform that applies information technology to the electric grid.

If we bring utilities, consumers, regulators, and legislators into concert, we will be able to achieve the often conflicting societal goals of energy security and environmental responsibility. The combination of national energy goals and market-driven carbon management policies will create new technologies, new jobs, and new business models. TR

PETER CORSELL IS FOUNDER AND CEO OF GRID-POINT AND A MEMBER OF THE TR35 (SEE PAGE 58).

INNOVATION

Broadening Technology's Reach

JOHNNY LEE SUGGESTS TAKING A BREAK FROM THE RACE FOR THE BEST TO CONSIDER HOW TO BRING NEW TECHNOLOGIES TO THE REST.

WE HAVE become obsessed with the extreme. To be interesting, a technology must be the fastest, the smallest, the biggest, the thinnest, the highest precision, or the lowest tolerance. We often invest immense resources in achieving these extremes. And while such work is essential to the progress of science and technology, its high cost has the unfortunate result that only a tiny fraction of the world can participate in it or benefit from the results.

When focusing purely on research goals, it is all too easy to overlook opportunities for reducing cost or eliminating complexity, because pursuing them might lower performance. But simple ideas that trade a bit of performance for a substantial saving in cost can have surprising and often powerful results

both scientifically and socially. Finding ways to put new capabilities within the reach of thousands—or millions—more people than was previously possible creates change on an immeasurable scale. Even beyond the direct benefits of usage are the indirect consequences of giving people power they never thought they would have. More people means more ideas—always a good thing in science. People become inspired. They become excited about exploring the potential of their new abilities. They choose to participate, to contribute, to create, to share with those who are like themselves.

I realize that I have not cited any specific examples. This is because I want to encourage you to think about how this idea could be applied in your own work, whether you are doing fundamental research or developing commercial products. Try asking yourself, "Would providing 80 percent of the capability at 1 percent of the cost be valuable to someone?" If the answer is yes, perhaps it is worth exploring whether that goal could be realized using alternative approaches.

Of course, the impact of a technology

depends greatly on the context of its application. But I can say that I have been fortunate enough to witness several occasions when my own work had broad effects. And the diverse types of research and development that have benefited from the principle of dramatic simplification continue to

surprise me. While it may not always be possible to apply that principle in your field, you can take pride in any effort you make to share the vast technological capabilities you possess.

JOHNNY LEE, A MEMBER OF THE TR35 (SEE PAGE 62), IS A RESEARCHER AT MICROSOFT, WHERE HE WORKS ON BRINGING RESEARCH CONCEPTS TO MARKET IN A PRACTICAL MANNER.

BIOFUELS

Battling Cellulose

MICHELLE CHANG EXPLAINS HOW INSIGHT INTO THE NATURE OF BIOMASS CAN BOOST THE EFFICIENCY OF BIOFUEL PRODUCTION.

GROWING societal responsiveness to the long-term environmental impact of human activities has increased the drive to develop sustainable and carbonneutral approaches to energy production. One of the most attractive possible substitutes for petroleum-derived products, such as oil and commodity chemicals, is plant biomass.

Feedstocks such as corn and sugarcane have been bred over thousands of years for their capacity to store high levels of starch (in the case of corn kernels) or sucrose (in the case of sugarcane stalks). Current industrial processes for biofuel production depend on traditional methods of converting these simple but valuable sugar, starch, and oil feedstocks into liquid fuels, but these techniques often leave behind a large

amount of more chemically complex agricultural material as waste.

The energy in biomass is derived by means of photosynthesis, in which plants use energy from the sun to synthesize carbohydrates from carbon dioxide and water. Thus, realizing the full potential of biofuels

depends directly on utilizing more of the carbon or carbon dioxide equivalents found in biomass. Most of the carbon in a plant is stored as lignocellulosic biomass, which is typically considered crop residue. Made up of cellulose, hemicellulose, and lignin polymers, these parts of the plant evolved to protect and preserve



the integrity of plant structures, so they are difficult to break down.

Existing strategies for processing and transforming this waste are limited, but many different ways of converting biomass to energy are under investigation. Much attention has focused on biological methods of breaking down lignocellulose into its constituent parts. Microbes and microbial communities have evolved to exploit biomass as a nutrient source, and they have developed enzymatic systems that degrade lignocellulose and metabolize the resulting molecules. But efforts to engineer microbes that can efficiently degrade lignocellulose will require more fundamental research on the way these complex systems function at a molecular level.

In parallel with this work, advances in functional plant genomics and engineering should lead to more rapid development of new crops with desirable energy-related traits, such as structurally modified cell walls that can be more easily degraded by emerging methods of lignocellulose processing.

Our laboratory is focused on elucidating the underlying design principles that explain complex chemical functions such as the multienzyme degradation of lignin. By combining fundamental biochemical studies with the tools of metabolic engineering and synthetic biology, we hope to learn how to rationally design new chemical functions in living systems.

MICHELLE CHANG, AN ASSISTANT PROFESSOR OF CHEMISTRY AT THE UNIVERSITY OF CALIFORNIA, BERKELEY, SPECIALIZES IN METABOLIC ENGINEER-ING. SHE IS A MEMBER OF THIS YEAR'S TR35 (SEE PAGE 69).

Authenticity in the Age of Its Technological Reproducibility



orn Originals," the 18th-century English divine and poet DEdward Young, the author of Night Thoughts, once asked, "how comes it to Pass that we die Copies?"

I twitter-often, several times a day. Most of my 140-character posts to the microblogging service are gnomic little mutterings, many are telegraphic self-advertisements (the quotidian, newmedia equivalents of "THE NILE IS SETTLED STOP SPEKE"), and some are bluntly promotional of stories on Technology Review.com. You'd think no one would read such stuff, but you'd be wrong. About 900 people follow me.

I Pownce, too-sharing images, music, or videos on the filesharing service. I also have a Facebook profile, where more than 700 "friends," most of whom I have never met, note my status updates, nod over the books I read, and peek at my photos. I Digg. Occasionally, I blog. And all my social-media activities are rolled up on FriendFeed. If you subscribed to my feed, you'd see how often I use social technologies: 24 times on Thursday, July 31.

I am not sure why I do all this. Anything I write for Technology Review or other publications reaches a far larger audience. I began because I felt I shouldn't write or edit stories about social technologies without having used them. Then, too, everyone young seemed to use social media all the time, and I didn't want to be generation-gapped by the little freaks. But I persisted because social technologies allowed me to talk with readers and sources in new, interesting ways. Also, it was fun! By now, using social media has become habitual, like keeping a diary.

But I will never use social technologies quite as the young use them, because I do not thrill to continuous attention and I value my privacy. Thus, the Jason Pontin who occupies the social space is a constructed persona, designed to be unchallengingly personable, humorous, and thoughtful. I am none of those things very often. The preoccupations of *that* Jason Pontin are professional: he thinks about emerging technologies all the time. And I never broadcast the substance of my inner life, because I know it would become insubstantial the moment I did.

Social-media Jason Pontin, in short, is a function of my business life. I know that this identity is inauthentic, because there is so much about which I do not post or blog. Do other habitual users of social media, whose social identities are as carefully constructed to attract attention, but who blog and post about everything (and thus feel no alienation), not know that those identities are inauthentic? Bemused by the difference between themselves and their social-media selves, are they mere Copies, cast from a few popular molds, endlessly reproduced among false friends?

This month in *Technology Review*, two authors write that they are. Emily Gould, a penitent, formerly inauthentic editor of the gossip site Gawker.com, reviews two books (see "'It's Not a Revolution if No One Loses," p. 96): Clay Shirky's Here Comes Everybody and a reprint of Walter Benjamin's The Work of Art in the Age of Its Technological Reproducibility. Contrasting the living new-media critic and the dead Marxist cultural critic, she writes, "Maybe, in the same way that Benjamin says the difference between 'follow[ing] with the eye, while resting on a summer afternoon, a mountain range on the horizon' and experiencing that same mountain at a remove (imagine a picture postcard) makes it harder to appreciate the real thing, social-media technologies are creating simulacra of social connection, facsimiles of friendship." Gould urges us, as "a pointless experiment," to stop using social media for a time and see our "world opening back up again."

Elsewhere (see "I Just Called to Say I Love You," p. 88), the novelist and essayist Jonathan Franzen condemns cell phones for their power to amplify inauthentic utterances and for what he describes as a kind of emotional coercion: "If the mother's declaration of love had genuine, private emotional weight, wouldn't she take at least a little care to guard it from public hearing?"

In Sincerity and Authenticity, a lovely collection of lectures delivered at Harvard by Lionel Trilling in the spring of 1970, the literary critic made a profound case for the importance of authenticity, and for its newness and fragility in our culture: "If sincerity is the avoidance of being false to any man through being true to one's own self, we can see that this state of personal existence is not to be attained without the most arduous effort." What, Trilling asks, is the enemy of authenticity? "No one has much difficulty with the answer to this question. From Rousseau we learned that what destroys our authenticity is society—our sentiment of being depends upon the opinion of other people."

Insofar as social technologies make us more dependent upon the opinion of others, they may be said to increase our inauthenticity and are to be deplored. But I am a technologist and an optimist about technology's capacity to expand and improve our lives. However hesitantly, I will continue to use social media. We'll work out the kinks. I choose to think that our private selves will survive and be enlarged by Twitter and Facebook as they were by earlier communications technologies. In his book, Shirky says that social technologies also increase the quantity of love in the world. Human nature, after all, is a movable feast, continuously evolving through technology. But write and tell me what you think at jason.pontin@technologyreview.com. – Jason Pontin



RAIL TRANSPORTATION IN SPAIN

The doors to the long-awaited high-speed rail line linking Madrid and Barcelona slid open in February 2008, connecting Spain's two main population centers and its two most significant hubs of business, technology, and research.

And this line, which represents the latest achievement in Spain's plans to connect the entire country with a web of high-speed trains, is far from the only news in Spanish rail. In the past few years, Spain has developed new metro systems, commuter rail lines, and suburban trains, some of which link to existing or developing high-speed lines. In addition, the Spanish companies that consult on the engineering of new lines, perform the construction and infrastructure development, build the trains, develop the signaling and information systems, and develop and build related parts have taken their expertise overseas as rail continues its explosive growth in the international market.

MADRID TO BARCELONA

Though Madrid–Barcelona might seem like the ideal route to begin a high-speed network, the Spanish government actually launched the system in Seville in 1992, when the city was to host the World Expo.

The new system completely rerouted an existing track that had swerved around mountains and avoided technically challenging terrain. Taking advantage of the latest construction techniques to tunnel through any existing impediments, the line also used the top trains and technology available at the time. It slashed travel time from about six hours to two hours and 20 minutes.

"This first experience caused something like high-speed fever," says Ignacio Barron, the Spanish representative to the Interna-

tional Union of Railways, who directs the organization's highspeed department. "Everybody wanted to build new lines and extend the networks."

Plans came up against a temporary roadblock when Spain, along with the rest of Europe, hit a financial downturn in the 1990s. But they picked up again in 1997. Since then, the Spanish rail authorities—RENFE (the rail operator) and ADIF (the company in charge of infrastructure and planning, which was originally part of RENFE)—have overseen the building and installation of more than 1,500 kilometers (nearly 1,000 miles) of high-speed lines. In 2003 the line linking Madrid to Zaragoza and Lleida, en route to Barcelona, began service. The line from Madrid to Seville branched out to nearby Toledo in 2005, and the first line opening up the northwest of the



country began service in December 2007. Soon thereafter, the line south finished up in the popular coastal destination of Málaga.

Madrid–Barcelona, however, is the current jewel of the system. Like the Madrid–Seville line, the new train to Barcelona features an entirely new route, new tracks, and new trains—these equipped with swiveling seats and full video and audio capability. And like the country's first high-speed line, this one dramatically slashes travel time. A trip that once took more than six hours now takes just over two and a half. The new trains offer a smooth, swift ride at about 185 miles per hour, or 300 kilometers per hour. When new signaling systems are installed (they're expected for fall 2008), train speeds will be able to reach 220 miles per hour, or 350 kilometers per hour, and travel time will shrink to about two hours.

By 2010 Spain will have the most high-speed tracks in the world, and plans call for 10,000 kilometers by 2020. This would place 90 percent of the population within 30 miles of a high-speed station.

Experts in the field cite two and a half hours as a time at which rail is competitive with air travel. The line to Barcelona, at close to 400 miles, now competes with one of the most trafficked air routes in the world: five million passengers are expected to use it in 2008

By 2010 the country will have the most high speed tracks in the world, with plans to expand to 10,000 km by 2020.

alone. A rail line from San Francisco to Los Angeles would be shorter, at 347 miles. And Boston is only 50 miles farther by road from Washington, DC, than Madrid is from Barcelona, meaning it would be theoretically possible—politics, land-use planning, and finances allowing—to build a train that could connect those U.S. cities in about three hours.

The Madrid–Barcelona line also represents the beginning of a new planned link to France. T.P. Ferro, a company created by a coalition of the Spanish and French construction companies ACS Dragados and Eiffage, has already broken ground on a new tunnel underneath the Pyrenees, the mountains that separate the two countries. The tunnel will eventually cut two hours from the trip between Barcelona and Toulouse, and travel time from Barcelona to Paris will be reduced to four and a half hours.

GROWTH OF RAIL

Current international trends support the development of train lines around the world. The cost of gas is spiking at the same time as rail technology has enabled ever-increasing speeds. The growing focus on limiting greenhouse gases adds to the interest in improving existing lines or developing new ones. According to RENFE estimates, a train traveler from Madrid to Barcelona generates 13 kilograms of carbon emissions, while the same trip by air generates 70 kilograms.

Today, there are about 625,000 miles of high-speed lines in the world, according to Barron. The International Union of Railways (know by its French initials, IUC) predicts three times that total by 2025, he says. According to these predictions, about a third of the world's high-speed lines will be in Spain.

"Before, trains were competing with cars; now today's highspeed trains are competing with planes," says Mario Oriol, export and marketing director of the Spanish railway-vehicle manufacturer Talgo. "That shows how fast the train technology has developed."

In Turkey, the government is building a high-speed track connecting Istanbul and Ankara; Spanish construction companies OHL and Guinovart are involved in building the line, and Spanish manufacturer Construcciones y Auxiliar de Ferrocarriles (CAF) will provide the trains. The company also recently won a bid to supply suburban trains to the Turkish city of Izmir. In Saudi Arabia, a high-speed line now in the planning stages will link Mecca and Medina. Two groups of Spanish companies—

CAF/OHL and Talgo/Isolux Corsán—are finalists in the bid, and CAF recently won a bid to supply eight trains to a future line.

Tracks are also under development in North African countries such as Algeria, Morocco, and Libya, an area of interest

and bidding for many Spanish companies. SENER, an engineering company whose transportation branch can cover a project's full cycle, has recently expanded into Algeria and is working on a metro and tramway. "Algeria has a lot of money from oil and gas, and they're investing it in infrastructure," says Cristina Ginés, SENER's director of international development. CAF is providing trains for the new Algerian metro.

Talgo and CAF have also supplied trains for rail projects in the U.S., including the Washington, DC, Metro and the Cascades railway in the Pacific Northwest. Many companies plan to submit bids when a final decision is made on plans for a potential highspeed link between San Francisco and L.A.

While Spain surges ahead in rail construction, China may be a close second, according to Barron. "China's rail system is creating a completely new network on the continental scale," he says. The Spanish information technology company Telvent is already operating in Chinese metros, and another Spanish IT company, Indra, is one of the finalists in the bid for control systems on new planned high-speed lines.

GLOBAL SOLUTIONS

By continuing to innovate, Spanish companies are able to grow along with the rapidly increasing market. Talgo, for example, is providing trains for Bosnia and Herzegovina, in the former Yugoslavia, where the rebuilding of the rail system reflects the advent of peace and economic development.

The project originated in 2000. "We took a train over— the first train to run on the line again after the war in Croatia and Bosnia–Herzegovina," says Oriol. "And during the test run we were guarded, leaving one station in Bosnia by helicopters from the Spanish army, which had been involved in humanitarian activities there. That was the project's kickoff."

Having worked with the conditions in Spain-steep mountains, tracks that curve around various topographical impediments—Talgo was well prepared for the mountainous geography of the Balkans. The company had developed lightweight aluminum trains with articulated cars, so that a train can be indivisible instead of comprising different segments. Thanks to its system of wheels that are mounted in pairs but not joined by axles, the wheels move along the track independently, leading to a more comfortable ride. These elements save energy, lower costs, and make trains faster, safer, and more comfortable.

"Our lightweight technology and independent and guided wheel system were ideal for that area," says Oriol. "In Bosnia, they found these trains quite interesting, because they saw that without any investment in infrastructure, the trains still reduced journey times by 20 to 30 percent." Talgo is supplying 81 passenger coaches, which will form nine trains.

Oriol says this project has important implications in the region: "Bosnia–Herzegovina is actually going to reëstablish all railway connections that existed in Yugoslavia before the war, from Sarajevo to Zagreb in Croatia, to Slovenia, to Belgrade in Serbia." The trains will be delivered in 2010, after track rehabilitation is complete.

The company also supplied trains to oil-rich Kazakhstan, which recently moved its capital from the south to the north. The previous Soviet-era train could make the journey in 21 hours, but Talgo trains reduce the ride to 13 hours, so an overnight train can bring workers from the newly designated capital back to their families down south for the weekend.

The weather extremes in Kazakhstan–from 45 °C (113 °F) in the summer to –45 °C (-49 °F) in the winter–posed technical challenges for Talgo engineers. They created a floating elevated floor to avoid touching the frame, which is exposed to the elements. They used different components and different steel alloys. "Basically, it was a complete redesign," says Oriol. The trains were delivered in 2003 and have been running smoothly, sun or snow. The gauge-switching trains for which Talgo is best known could also be useful should Kazakhstan and China decide to link lines, since China uses a narrower rail gauge than Kazakhstan.

FUNDING THE GROWTH

When it comes to financing, one of the trends taking place around the world is the privatization of public projects. A company, instead of the government, will supply all the necessary development funds for a project such as a new highway. The companyor companies—will then be repaid through the tolls or fares that would traditionally go back to government coffers.

This approach is becoming especially popular in countries where cash for up-front investments is scarce. CAF, which has been working in Mexico for 14 years, won the 30-year concession for the new suburban train line from Mexico City out into the surrounding state. The company is responsible not only for supplying the trains but for overseeing the construction, signaling, and telecommunications—all the necessary aspects of developing a new train line. Companies involved in the project as subcontractors include construction company OHL for the civil works, Indra for ticketing, Thales for signaling and telecommunications, Inabensa for electrification, and Telvent for the control center.

CAF sees this as a strategic beginning. "We saw that there was a lack of funds for investment [in Mexico]," says Luis Giralt, CAF's international director for Latin America, "but certainly no lack of a need for this type of transport."

After two years of construction, the line began operation in the spring of 2008. "Before, passengers along this line took an hour an a half to get into Mexico City," says Giralt. "Now the commute takes only 25 to 27 minutes." CAF has managed to hold down prices to match those on the bus line.

"The response so far has been very positive," Giralt says. "People see that the trains are modern and air conditioned, and they get from home to work much faster and much more comfortably than before."

India, which is planning a multibillion-dollar upgrade and expansion of freight and passenger rail, is also investigating concessions as a means of financing, constructing, and supplying the rail lines. Isolux Corsán, a top Spanish construction company that also specializes in engineering, electrical wiring, and signaling, looks forward to the potential. "They're planning concessions in railway stations, for freight corridors," says international-business director Álvaro Rengifo. "We have local partners and are getting ready."

They company already has rail projects in development around the world. Rengifo says that experience with all aspects of rail development along Spain's high-speed corridors has helped Isolux Corsán grow internationally and win concessions abroad.

RAIL REVIVAL

Because high-speed rail allows for easy, zippy travel between urban powerhouses, it has carried economic benefits to smaller cities along the way.

When the AVE (the Spanish acronym for the country's high-speed system) brought Ciudad Real and Puertollano to within an hour of Madrid, both cities were strengthened economically. The newfound proximity solidified Ciudad Real as a university and regional business center, and the effect spilled over into nearby Puertollano.



Along the Madrid–Seville line, the city of Córdoba, formerly a regional industrial center, took the arrival of rail into account to manage new development. City planners moved the rail lines underground and rebuilt the station, freeing swaths of green space, and designed a corridor of hotels, conference centers, and other facilities to attract visitors. The city profited both physically and economically.

Zaragoza, midway between Madrid and Barcelona, has already reaped the benefits of the high-speed line that reached the city in 2003, and it expects to gain even more by the time the line is complete. The city, already a regional hub, capitalized on the new station by expanding related businesses and services and by hosting 2008's International Exposition on Water and Sustainable Development. In the past, travelers rode for three to four hours to reach Zaragoza from Madrid or Barcelona; the AVE cut that time in half. The city has developed hotels and facilities to attract meetings and conferences. "Zaragoza can serve as the point between the two cities," says Jose Luis Abad of the group High Speed Zaragoza. "We've been able to take advantage of new line to modernize the city—transform it into a modern center, a perfect business meeting place." Zaragoza also houses Indra's high-speed control center, with its walls of vibrant lines and dots representing trains as they move around the country in real time.

Mikel Murga, managing director of the Spanish consulting

firm Leber and a lecturer at MIT, has served as an advisor on rail issues around the world. One city where he consulted was Bilbao, which opened its metro system in 1995. "Because of the subway, the city has evolved and changed," he says. "Elected officials have been emboldened to act in ways that would never have been possible before the subway."

Murga explains that the city has been able to focus planning on pedestrian traffic instead of cars; one project calls for making the downtown region a pedestrian-only plaza. "These are the kinds of changes that can only be explained by the contribution of rail," he says. The economic benefits reach individuals, too. "Young people who are trying to pay a mortgage—if they need two cars because they live far out of the city, there's a tremendous impact on their budget," Murga says. "We've made estimates of an additional 2,000 euros (currently about \$3,200) per person per year, depending on whether someone has to rely on a car or not."

TRAINS TO THE FUTURE

When Spanish rails were first placed, in the 1800s, they were significantly wider than the tracks in France and the rest of Europe, walling the country off from its neighbors. In the 1960s, however, RENFE decided to operate trains that could easily move to French lines. To meet this need, Talgo designed its signature variable-gauge trains,



which can switch from one gauge width to another. The company has been operating such trains between Madrid and Paris since 1968.

For the new high-speed lines, the Spanish government decided to build the entire system on standard tracks to facilitate travel to neighboring European countries. Both Talgo and CAF came up with solutions for automatic systems that allow trains to switch between gauges without coming to a complete stop. In both systems, the change—which in the past took up to an hour—takes only about four seconds.

Meanwhile, both CAF and Talgo have developed different types of proprietary technology in what are called "tilting" trains. Tilting technology detects where and when the track curves, and it enables the train to lean into the center of the curve. Tilting allows even conventional trains to travel faster through these parts of the track.

By introducing aluminum bodies for trains in place of conventional steel, Talgo also cut the weight of the cars by about 30 percent, significantly reducing energy needs. This strategy has since been adopted by other high-speed manufacturers. Today, train companies are investigating the use of composites, which are already widespread in the aerospace industry. A CAF train

under development has a composite floor, which reduces the weight of this component by a full 70 percent. Talgo, which also has projects involving composites, is now looking into hybrid and solar-powered cars as well.

CAF heads a research project partially funded by the Spanish Ministry of Industry, in consortium with six companies and nine research centers, that seeks to improve the interoperability, energy efficiency, speed, and comfort of high-speed trains. Called AVI-2015, the project is focusing on improving the trains' tilting properties, adapting their shape to make them more aerodynamic, and finding more efficient ways for trains to run on different voltages of electricity. CAF expects that these improvements will allow high-speed trains to run efficiently and comfortably on standard train tracks as well.

CAF is also working to improve its trains for tram and light rail, a significant part of the company's business. It's developing trams that have energy storage systems on board, eliminating the need for wires that run above the trains along the outdoor tracks. This is especially important in historic areas with monuments and cathedrals, says Javier Goikoetxea, CAF's research project coördinator: "Many citizens complain about power lines in these

regions." The new systems will also save infrastructure costs for local governments. The company has won recent tram contracts in Edinburgh, Scotland, and in Antalya, Turkey.

Spanish train companies' research and innovations extend to infrastructure development as well. For the Guadarrama tunnel north of Madrid—the country's longest, and the first of this length in the world to have no intermediate ventilation shaft—the company Zitron designed a completely new ventilation system. It uses a series of tubes, improved aerodynamic fans, and air curtains—a pneumatic closure system using jets of air—to push fresh air through the tunnel.

"We've developed a very sophisticated system, and people from all over the world have visited, as it's something quite new," says Zitron's Pedro Quiros. The company has won railway ventilation contracts in Australia, Africa, Europe, and the U.S.

The construction of tunnels for high-speed rail "is without doubt one of the most complicated aspects of rail infra-

Passengers in the Spanish

train system are guaranteed

that they will arrive on time or

their fare is refunded.

structure," said Manuel Arnáiz Ronda, the president of the Spanish Association of Tunnels and Subterranean Civil Works, at a recent meeting in Spain. But Spain, he said, is "one of the top in the field," thanks to the years of experience its construc-

tion companies have gained in boring through challenging geological structures and navigating around urban obstacles.

ACS Dragados, which is involved in the Guadarrama tunnel, capitalized on that experience to win the bid for the expansion of the New York City subway, in partnership with an American company. ACS Dragados is constructing east-side access tunnels, using two hard-rock boring machines it owns. These are the first tunnels to be built in the subway system in 25 years, and the first ever to be built with boring machines. The system draws on the same techniques the company used to bore under the Pyrenees.

TIMELY ARRIVAL

Passengers in the Spanish train system are guaranteed that they will arrive on time or their fare is refunded. That doesn't happen often; RENFE prides itself on a 98.5 percent punctuality rate. This performance owes much to advances in information systems and signaling.

At the AVE control center in Zaragoza, Indra—one of the top European information systems companies—uses a complicated network of track sensors, signaling technology, radio transmitters, and computer systems to control Spain's high-speed network. The DaVinci system, which was developed for ADIF and began operations in 2003, integrates information about the trains and the rail system and updates all that information in real time or within a few seconds.

High-speed rail demands precise information gathering and transmission. Not only does the control center collect data on exactly where each train is at any given moment, but it gathers other types of crucial information as well. For example, data from detectors that test the temperature of the brake boxes helps the system avoid overheating and the resulting brake failure. The system also collects information on electricity demand in every part of the line. Fiber-optic sensors detect even small fallen objects along rail paths and then sound an alarm.

Jose Miguel Rubio, DaVinci's rail information system manager, says new research focuses on automating even more features of the control system, sidestepping human decisions. "So if you have a conflict in real time, where two trains want to go onto the same track," says Rubio, "the automatic routing system starts to scan the track for the best route to solve the conflict." The company is also involved in building a super control center in Madrid, which will oversee all tracks in Spain, not just the

high-speed ones.

Newer, more accurate signaling systems will allow trains to run even faster. Says Javier Rivilla, project manager at Indra, "As we begin to increase rail speed, I believe we will keep on innovating and advancing within

this system, making everything even easier to coördinate and even more automatic." These developments will increase the productivity of the entire rail system, but they will also demand increasingly precise data and data transmission.

Signaling presents one of the greatest challenges both in making trains faster and in achieving interoperability across Europe. Trains traveling at high speeds need at least 8 kilometers to brake, and 12 kilometers to brake smoothly–something impossible with road signals such as traffic lights.

"These signaling installations have to be designed in such a way that if you have a problem in one site, the system has to know at each moment where the rest of the trains are and get the information to all the trains, allowing them time to slow down and prevent a collision," says David Sanz, account manager for sales and marketing at Dimetronic, a Spanish signaling company that has been involved in a variety of Spain's high-speed projects.

In the past, however, each country used its own signaling technology, so trains crossing borders needed to be equipped with a variety of systems to read the different signals. To deal with this problem, in the early 1990s the European Union called for a standardized system. Known as the European Rail Traffic Management System (ERTMS), it was developed to be open and available for use by companies around Europe; any company could develop a system that would meet the European standards. The Spanish government, working in conjunction with top Spanish companies, pioneered the use

of this system in all the country's highspeed rail lines.

In what's known as ERTMS Level 1, all the track information, such as the location of trains, is centralized in a computer. The information is relayed back to trains by equipment along the track. The accuracy of this system allows trains to reach speeds of 250 to 300 kilometers per hour. Level 1 was first installed in Spain in a pilot program in 2002 and has been used for all new high-speed lines built since.

ERTMS Level 2, which is in final testing, uses less rail-side equipment and provides greater accuracy, so that trains can run even faster and more of them

"Now, with the

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can run on a given track. Level 3, which is still under development, will allow still higher speeds and train densities.

Increased precision in transportation technology has allowed trains to run faster and more frequently, agrees Arturo Corbi, international director of transportation at

Telvent, which operates control systems for trains and subways. "Ten years ago, in one lane there were probably two or three trains, and now you can have ten," he says. "Now, with the increased ability to know exactly where the trains are at any given second, you are able to have effective and direct control over the train that in the past was not possible."

Telvent's expertise in control systems and related technology won it the bid to design and provide the ticketing system for the first subway system in Tianjin, China, a city of about 13 million inhabitants. The local government wanted to try a different approach, "so we decided not to use tickets at all," says Corbi. "It was a challenge and a risk to base the system entirely on one technology, and

the first such system in China."

Instead of individual tickets, the system relies on plastic cards, similar to Boston's Charlie Card or the DC subway's SmarTrip card. Both those systems, however, also offer the option of standard ticketing. In the system Telvent designed for Tianjin, passengers buying individual rides get tokens equipped with the same chip that's in the plastic card, creating a "contactless solution."

There are many benefits, according to Telvent. "You help make it comfortable and easy for the users, and you avoid maintenance costs for the operator [by having one system instead of

two]," Corbi says.
"Also, there's no
paper, so it's more
sustainable." The
line opened in
2005 and has
been running
successfully for a
year; the fare system will now be
extended to two
additional lines.

Telvent has applied what it learned from the Tianjin project in Latin America, in

Monterey, Mexico, and in a train line in Venezuela. The company is also working on technology that makes the system more accessible, such as voice-recognition vending machines for the visually impaired.

Those involved in rail say it's an exciting time in the expanding sector. "There are a lot of technological improvements, a lot of work to be done, a lot of projects going on," says Indra's Jose Miguel Rubio. "Ten years ago, rail couldn't reach the current speed, and now it can easily compete for medium distance with planes. It's the ultimate transport solution."

Resources

ICEX (Spanish Institute for Foreign Trade) www.spainbusiness.com

ADIF

www.adif.es

CAF

www.caf.es

Dimetronic

www.dimetronic.es

Indra

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Diffusion spectrum image of the human cortex

FORWARD

FINDING THE CORE OF THE BRAIN

A new mapping approach identifies the hub of the human cortex

THE ICONIC image of the brain is a misshapen, yellowish lump. Existing technology can show which parts of the lump light up when people think, but a real understanding of how the brain works demands a better picture of the nerve fibers that ferry electrical signals between brain cells. Those fibers, however, are so small and tangled that researchers haven't been able to see them clearly.

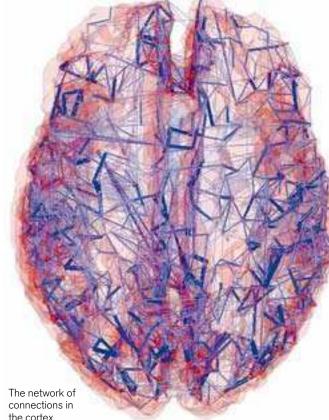
Now, an international team of scientists has combined a new variation on magnetic resonance imaging with mathematical analysis to generate the first detailed map of the network of connections in the human cortex, the part of the brain responsible for higher-order thinking.

Diffusion spectrum imaging-which tracks water molecules moving along nerve fibers-gave the scientists a wiring map of the cortex, revealing points where multiple nerve fibers converged. The scientists then used a

mathematical technique to repeatedly prune away the connection points with the fewest links. "If you do it gradually, you end up with a set of nodes remaining that are highly interconnected," says Olaf Sporns, the Indiana University researcher who performed the analysis.

The most highly connected node is at the back of the head, and it lies on the shortest path between many different parts of the neural network. Not only does it have many internal connections, says Sporns, but it's "highly central with respect to the rest of the brain."

The researchers want to use the imaging technique to look at conditions such as schizophrenia, autism, and Alzheimer's disease, all of which have been linked to disturbances in brain architecture. "We would like to know where the disturbances are and whether we can understand something about the clinical condition based on the connectivity," says Sporns. -Emily Singer



WEDEEN, PATRIC HAGMANN, OLAF SPORNS

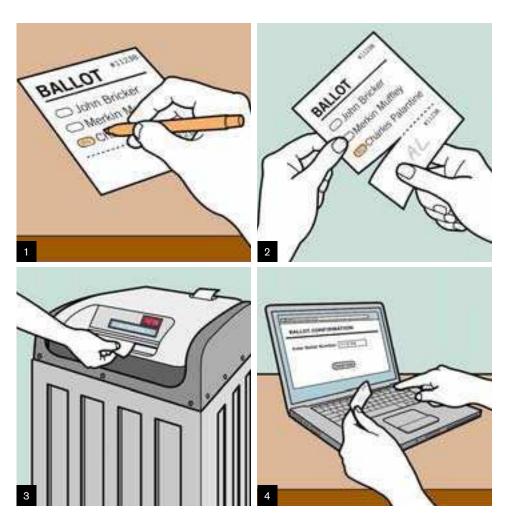
FLAWLESS VOTE COUNTS

Cryptography lets voters confirm that their ballots were tallied correctly

SINCE THE 2000 election debacle, optical scanners have become the most common U.S. voting technology. Voters fill in a bubble next to a candidate's name on a paper ballot and feed it into the scanner. The scanners tally votes automatically, saving time, but they also leave a paper trail that can be hand audited.

Even optical scanners can misread stray marks, however, and any voting machine can be tampered with after the fact. But a cryptographic system developed under the leadership of electronic-cash pioneer David Chaum can guarantee that every vote cast using an optical scanner is correctly recorded.

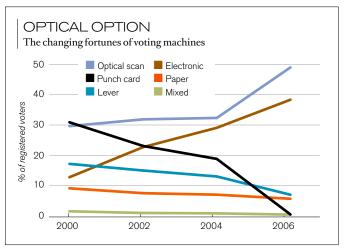
In the voting booth, instead of filling in a bubble in pencil, the voter uses a special pen to reveal a code printed inside the bubble in invisible ink. Later, the voter can enter the ballot's serial number on an election website, which looks up the ballot and displays the associated code. If the code matches the one exposed in the booth, the vote was correctly tallied. But because the codes are never publicly correlated with candidates' names, the voter's privacy is maintained-and there's no



TAMPER-PROOF TALLY: A new cryptographic system can guarantee that votes cast using optical scanners are counted correctly. (1) The voter uses a decoder pen to expose a unique, randomly generated code printed in invisible ink next to a candidate's name. (2) The voter writes the code on a detachable receipt marked with the ballot's serial number. (3) An ordinary optical scanner reads the ballot, just as it would one marked in pencil. (4) At home, the voter enters the ballot's serial number on an election website. If the site pulls up the corresponding code, the vote was recorded accurately.

evidence to give to would-be vote buvers.

Until now, it's been easy to dismiss cryptographic voting systems as academic exercises, but the fact that the new system is designed to work with optical scanning gives Chaum hope that it will catch on. "We're ready," he says. "There's no risk. If you add it on, it doesn't interfere with what you had, and if there's a problem with it, you can just ignore it." -Matt Mahoney



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BROADBAND ANYWHERE

Sprint turns Baltimore into a giant wireless hot spot

WHAT IF your laptop could wirelessly connect to the Internet as easily as your phone connects to the cellular network-with broadband data rates to boot?

That's the promise of a technology called WiMax, and in September, in the greater Baltimore area, Sprint is launching its first WiMax network. Several smaller companies offer regional WiMax service in the U.S., but Sprint has the national reach to take the technology into the mainstream.

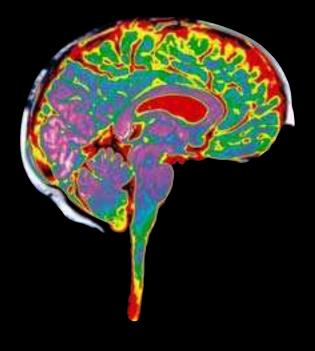
Unlike Wi-Fi, WiMax uses licensed radio spectrum, so it can turn up the power without jamming other devices. A WiMax signal will travel kilometers, as opposed to the 20odd meters of a Wi-Fi signal.

In Baltimore, Sprint promises a data rate of two to four megabits per second. WiMax achieves that kind of speed

two ways. First, it uses antennas with multiple sending and receiving elements; second, it divides bandwidth into subfrequencies that overlap but don't interfere with each other, so more data can be crammed into a swath of spectrum.

But the same technologies are also the basis of the longterm evolution, or LTE, which Verizon champions as an alternative to WiMax. "When you look at 2015 and see who

will have the bigger market share," says Arogyaswami Paulraj, a Stanford professor who helped pioneer both technologies, "until a year or two ago, the general view was that LTE might actually have a little more." But LTE probably won't be ready for deployment until 2011, Paulraj says, and WiMax is already popular in India. "I think WiMax is pretty well positioned at this point," he says. -Larry Hardesty



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WEB SERVICES

RIEF HISTORY OF ROBLOGGING

Twitter and its competitors have spawned an entire ecosystem

MICROBLOGGING services—which let subscribers post short personal updates online or broadcast them as text messages-have inspired a slew of ancillary services. Clients are desktop or mobile-device applications that access microblogs' content. Toys are sites that present the content in new ways, often combined with other data. Accessories meet needs specific to microbloggers—such as a way to shorten URLs so that they fit inside status updates. This time line of service launch dates provides a snapshot of the whole ecosystem. -Erica Naone

MARCH 1, 2006 Facebook launches status updates JULY 13, 2006 Twitter The first major microblogging service

MARCH 18, 2007 This early Twitter toy set the tone for later: messages from Twitter pop up on a map of the world and fade as quickly as they

OCTOBER 9, 2007 Google purchases Jaiku but leaves it to languish; its plans for the service remain unclear

> OCTOBER 22, 2007 During the San Diego fires, people use Twitter to update friends and family on the situation and their whereabouts

APRIL 4, 2008 Seesmic buys Twhirl, touting the client's ability to make posting easy

in all media, across plat-

APRIL 10, 2008 A Berkeley student uses Twitter to get help when arrested by Egyptian police

Identi.ca The open-source service

JULY 2, 2008

Identi.ca launches, hoping to spark a collection of interoperable sites that offer microblogging

APRIL 11, 2008

After testing its real-time search tools on several Web services, Summize announces that it will focus on Twitter

FEBRUARY 28, 2008 LinkedIn launches status

NOVEMBER 12, 2007

DECEMBER 13, 2007

OCTOBER 1, 2007

FriendFeed combines

posts from multiple services, letting people read

and comment on them without having to join the

services

JULY 12, 2007

status updates

MySpace launches

JULY 17, 2007

witter for iPhone

Hashtags tracks the use of hash

marks, a way to label posts by topic; the system helped people follow

the progress of the San Diego fires

Built using Adobe's AIR technology, Twhirl allows users to post to several microblogging services at once

APRIL 23, 2008 System architect Blaine Cook leaves Twitter, which has had trouble meeting escalating demand but has begun to rebuild its infrastructure

JULY 14, 2008 Twitter buys Summize; thirdparty sites struggle as Twitter, trying to keep its servers from overloading, keeps changing the rules for accessing its data

Toys Clients

LAUNCH

Accessories

Acquisitions/events





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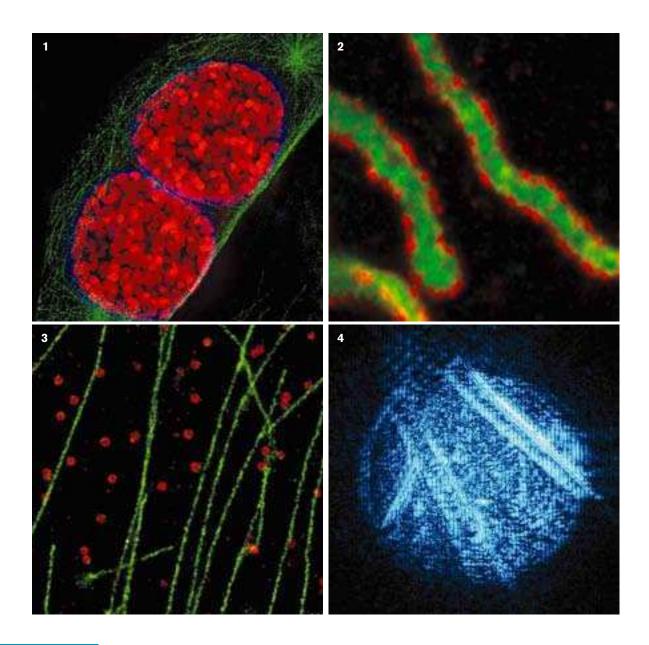
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LIFE LEFT IN LIGHT

Light microscopes make a comeback

LIGHT microscopes have had a basic limitation: they couldn't image objects smaller than half the wavelength of light itself, leaving cellular machines like mitochondria a blur. But electron microscopes work only on dead cells. A new generation of light microscopes has broken the resolution barrier and could revolutionize biology by letting scientists glimpse the molecular workings of living cells. Here are four of the most promising examples. -Katherine Bourzac

- 1. This image of two cells preparing to divide was made by illuminating the cells with stripes of light called an interference pattern. The red clusters are DNA, and the green fibers are structural proteins that will help separate the cells. (John Sedat and Peter Carlton, University of California, San Francisco)
- 2. This is one of the most detailed images ever captured of the subcellular organs called mitochondria. The imaging method uses two beams of light: one cancels out part of the other, effectively shrinking it. (Stefan Hell, Max Planck Institute)
- 3. A third approach uses colorful fluorescent probes that can

- be rapidly switched on and off to resolve details like these structural filaments (green) and pouches for carrying nutrients and viral intruders into the cell (red). The resolution of these pictures depends on the number of images used to make a composite. (Xiaowei Zhuang, Harvard University)
- 4. This image of a neuronal synapse was made using a grating called a superlens, which is structured at the nanoscale to gather up light waves that carry details missed by conventional lenses. The technique's resolution is comparable to that of transmission electron microscopy. (Nicholas Fang, University of Illinois)

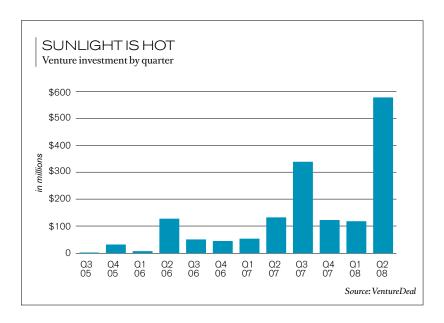




New twists on three leading solar technologies

AS OIL prices have climbed, so has venture investment in alternative energy. According to Venture Deal, a venturetracking service in Menlo Park, CA, solar-power startups in particular have seen a three-year surge, from a low of no venture investment in the third quarter of 2005 to a high of more than half a billion dollars in the second quarter of this year.

The most popular approach to solar power remains photovoltaic panels made from crystalline silicon. But recent years have seen the commercialization of two rival technologies: thin-film solar cells, in which layers of light-absorbing materials are deposited on glass or even flexible plastic, and solar concentrators, which conserve silicon by using mirrors or optics to focus the sun's energy onto a smaller area. With VentureDeal's help, Technology Review has identified solar startups with innovative variations on all three approaches. - Dean Takahashi



CALISOLAR

Most solar cells are made from very pure-and thus expensive-silicon. But CaliSolar can make do with silicon that has a thousand times the impurities and can cost a sixth as much. That could mean real savings, since silicon can represent a quarter to a third of the cost of making solar cells. Usually, impurities lower cells' efficiency by reabsorbing freed electrons. But CaliSolar's manufacturing process herds impurities together, so electrons are less likely to hit them. The company's cells convert 15 percent of solar energy into electricity, putting them in the ballpark of conventional cells.

Product: Solar cells made from "dirty" silicon

CEO: Roy Johnson

Location: Sunnyvale, CA

Funding: \$13.4 million

Funders: Advanced Technology Ventures, GlobeSpan Capital **Partners**

URL: calisolar.com

WAKONDA **TECHNOLOGIES**

Thin-film solar cells are inefficient but cheap. Where there's room to put up a lot of them, they're cost effective, but to compete elsewhere, they'll have to get more efficient. Wakonda has found a way to coat a metal foil with some of the most efficient photovoltaic materials known, such as gallium arsenide. The company says that its thin-film cells will be even more efficient than silicon panels. Gallium arsenide is expensive, but Wakonda claims that its films will cost as little as its competitors'.

Product: Thin-film solar cells from superefficient semiconductors

CEO: Les Fritzemeier

Location: Fairport, NY

Funding: \$9.5 million

Funders: Advanced Technology Ventures, General Catalyst Partners, Polaris Venture Partners, **Applied Ventures**

URL: wakondatech.com

PRISM SOLAR **TECHNOLOGIES**

Prism has engineered a new type of solar concentrator by inscribing holograms in a transparent medium sealed between pieces of glass. Much of the light that strikes a conventional solar cell generates waste heat rather than electricity, but Prism's holograms can divert unproductive wavelengths of light away from the cell. As a consequence, it can concentrate the productive wavelengths more intensely without fear of overheating. The company claims that it can concentrate light two to three times as much as its competitors can.

Product: Holographic solar concentrators

CEO: Rick Lewandowski

Location: Lake Katrine, NY

Funding: \$8.5 million

Funders: Counter Point Ventures, I2BF Venture Capital. Phoenix-Fire II, Walt Robb

URL: prismsolar.com

REALITY

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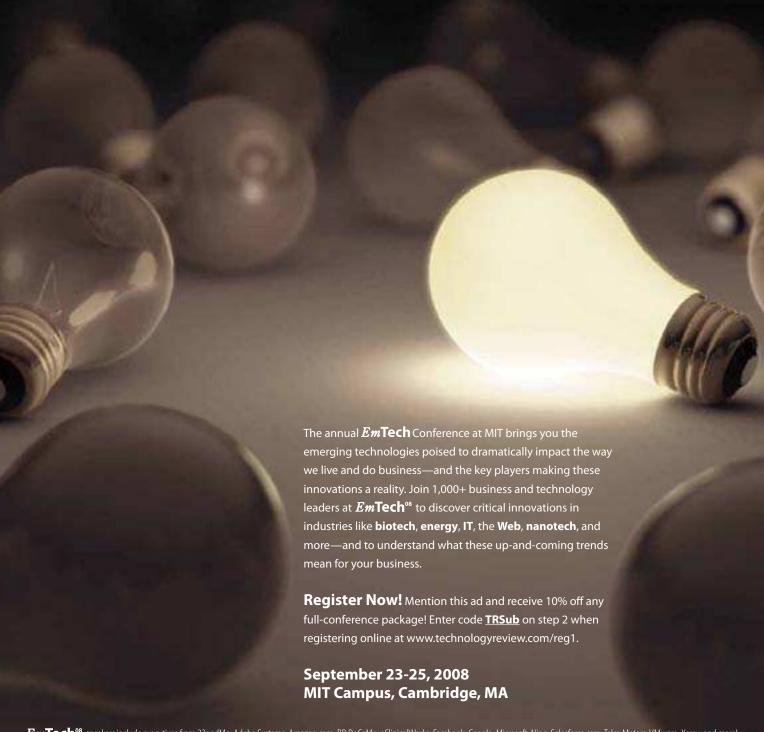
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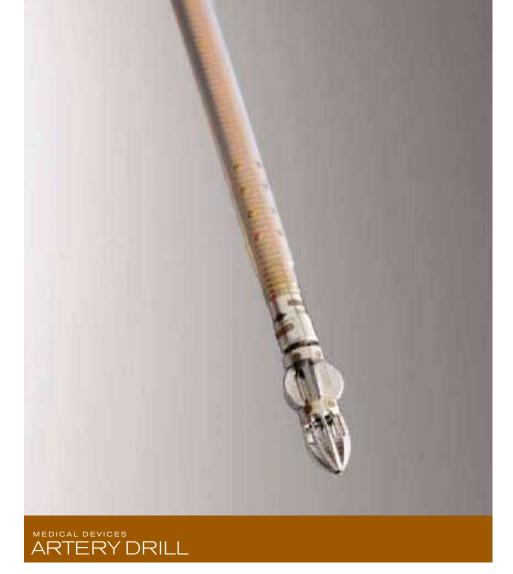
A NEW self-focusing webcam is the first consumer product with a liquid lens. The lens, from the French company Varioptic, consists of an oil-based and a water-based fluid sandwiched between glass discs in a drum the size of a watch battery. An electric charge causes the boundary between the oil and water to change shape, altering the lens's focus. Because the lens has no moving parts, it's more durable than other lenses of similar size.

Product: SnakeCam Cost: About \$22 for the 1.3-megapixel version, \$24 for the 2-megapixel version Source: varioptic.com

Company: Akkord







AROUND 10 million Americans have peripheral-artery disease—plaque buildups in the arteries of their arms and legs that can cause chronic pain and even lead to amputation. Surgeons treat the condition by inflating balloons inside the artery or by inserting metal-mesh tubes known as stents, but a new drill-tipped catheter could be a better option. The drill has blades that expand and contract to fit the artery, plus a vacuum that sucks up the debris.

Product: PV Atherectomy System Cost: Competitive with similar devices, which cost about \$3,000 Source: pathwaymedical.com Company: Pathway



WIRELESS

High Definition Closes In

A NEW wireless transmitter from IDX will let high-definition TV cameras go where they never could before. The transmitter can send a high-definition signal 150 feet, saving cameramen from stringing cable in harsh or cramped environments or setting up costly, bulky microwave transmitters. What's more, the video signal is uncompressed, so producers don't have to worry about time delays when they're cutting between cameras at, say, sporting events or political rallies.

Product: CW-5HD Cost: \$5,995 Source: idxtek.com/products Company: IDX



GESTURE-CONTROLLED LAPTOP

TOSHIBA'S new Qosmio laptop is the only gesture-aware computer on the consumer market. Software loaded on the laptop lets users control Microsoft programs like PowerPoint and the Windows Media Player with just a wave of the hand. Using a webcam built into the screen, the computer can distinguish three gestures—a raised palm, a moving fist, or a thumb flick—from up to 10 feet away.

Product: Qosmio G55-Q802 Cost: \$1,549.99 Source: explore.toshiba.com Company: Toshiba

GLASSES-FREE 3-D

FORGET about silly-looking, uncomfortable 3-D glasses. Philips's new 3-D displays create the illusion of depth by overlaying an LCD screen with tiny lenses that direct slightly different images to the viewer's eyes. The illusion persists within a 120° viewing area. The displays work only with specially created content, so Philips is currently marketing them for use in promotional displays-at malls, casinos, and movie theaters, for instance. But it hopes to have 3-D TVs in homes within a few years.







FIRST TIDAL POWER GENERATOR

THIS SUMMER, the first commercial electrical generator to draw power from the ocean tide began supplying Northern Ireland with energy. Installed in an inlet near Belfast, the generator works much like a wind turbine, with massive blades turned by the tide's current. The angle at which the blades meet the current can be changed: rotating the blade face 180° lets the turbine catch the tide in both directions, while smaller rotations lessen the force exerted on the turbine, preventing damage.

Product: SeaGen Cost: 30 to 40 cents per kilowatt-hour; a planned installation with seven turbines will lower that cost to about 20 cents per kilowatt-hour Source: www.seageneration.co.uk Company: Marine Current Turbines

THE WEB

An eBay for Interest

MONEYAISLE aims to turn the tables on the normal workings of the financial industry. A customer who wants to open a bank account or buy a CD logs on to the MoneyAisle site, and banks compete for the deposit by offering different interest rates. The system helps customers find attractive deals and opens up the market to smaller banks, which pay only if they acquire new customers. MoneyAisle plans to expand into loans.

Product: MoneyAisle.com Cost: Free for customers; banks pay a variable transaction fee Source: www.moneyaisle.com Company: NeoSaej



A NEW computer-aided detection system could help identify breast cancer earlier. The system uses pattern-recognition algorithms to analyze images collected through digital mammography. It highlights suspicious spots that radiologists may have missed on first examination, prompting them to review the mammograms and determine whether further tests are necessary. According to its manufacturer, iCAD, the system detects up to 72 percent of treatable cancers an average of 15 months earlier than mammography alone.

Product: SecondLook Digital computer-aided detection system Cost: About \$70,000 Source: icadmed.com Company: iCAD



60-MEGAPIXEL PHOTOGRAPHY

A NEW digital-camera imaging system-a semiconductor sensor and associated electronics-is the first with 60 megapixels. Previously, semiconductor slabs large enough to fit that many pixels without degrading image quality were prohibitively expensive. The new sensor still isn't cheap, but it allows digital cameras to meet and even exceed the performance of the medium-format film cameras many professionals prefer.

Product: P 65+ Cost: \$39,900 Source: phaseone.com Company: Phase One

DIAGNOSTICS

MicroRNA Diagnostics

THE FIRST diagnostic test to classify cancers by differences in microRNAs-small pieces of RNA that regulate genes—will soon be on the market. The test distinguishes two types of lung cancer and should help doctors tailor treatments to their patients' needs. Scientists say that tests based on microRNA profiles could prove

more sensitive and reliable than existing methods, whose accuracy depends heavily on the judgment of the people analyzing them.

■ Product: MicroRNA test for lung cancer Cost: Comparable to that of other molecular tests for cancer, which are priced at around \$3,000 to \$3,500 Source: rosettagenomics.com

Company: Rosetta

Genomics



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Q&A

A pioneer of personal computing says the U.S. needs a CTO.

itch Kapor likes beginnings. In 1982, he founded Lotus Development, which made the popular spreadsheet program Lotus 1-2-3. In 1990, he cofounded the Electronic Frontier Foundation, a political-advocacy and legal organization that champions free speech and privacy. And in 2003, he became the founding chair of the Mozilla Foundation, which is responsible for the opensource Web browser Firefox. Today, Kapor sits on the boards of such companies as Linden Research, and he heads his eponymous foundation, which provides grants to San Francisco Bay Area organizations working with lowincome communities on educational and environmental issues.

Last fall, Kapor was called upon to help Senator Barack Obama define his technology positions. Kapor suggested that Obama, if elected president, should install a federal chief technology officer. Conservatives grumbled at the idea of another layer of bureaucracy, but Kapor and others in Silicon Valley say the government needs cohesive technology practices and policies.

Kapor recently spoke with Technology Review's information technology editor, Kate Greene.

TR: Why does the country need a CTO?

Kapor: The underlying premise is that tech is inextricably intertwined with virtually everything. You can't talk about homeland security or education or energy without it being in large part a conversation about technology. The president will be well served if policy making is done in a more technologically sophisticated way.

What would a CTO worry about?

We're in the middle of the pack as a nation in terms of broadband deployment. We need to have policies that will enable us to catch up and do so in a way that's ubiquitous and affordable. I also think tech policies that stimulate innovation in the economy are very important, because innovation is the engine of growth. Getting the balance in intellectual-property law that will stimulate innovations is therefore very important. Net neutrality is also a huge issue in ensuring the Internet isn't controlled by the people who own the wires, because that is just going to impede innovation. Would the CTO oversee the federal

government's infrastructure? Demand that networks of agencies work together?

The advantage of a CTO is that there can be coördination. There's a ton of work that goes on within different agencies: there needs to be someone to identify the best ways of doing things and some common practices.

In practice, how would a CTO do that?

You could take practical steps in terms of data and data storage and its accessibility and availability, both across department and agency boundaries and to the public.

How is that different from the job of a national chief information officer?

That's a good question, and I'm not sure if I have a good answer. It seems to me that whatever you call it, it's helpful to put the coördinating activities and policy advisory piece under the CTO umbrella. That feels different from a CIO.



Watch a longer version of this interview with Mitch Kapor: technologyreview.com/qanda

How much actual power would the position have?

How much formal authority versus soft power a CTO has is clearly a very big issue. No matter how much formal authority you have, if you don't have soft power you're not going to get anything done. So you want somebody who is taken seriously, and it would help if the president makes it very clear that this is a serious position. Second, it should be the kind of person who is able to lead by influence and not by command. I personally think that might well be sufficient. You mean the CTO would be a moral force,

equipped only with soft power? The idea of trying to give a CTO for-

mal authority over other bodies and agencies has a very high risk of failure. It sounds as if the CTO would have no operational responsibility and be unaccountable if anything went wrong.

I don't know. I was a volunteer on a committee that worked on the proposal last fall, so what I know about are the discussions that led up to the announcement. The plan of record for the CTO doesn't get into a level of detail that would address this, and I don't have visibility on what has or hasn't happened since the plan was announced.

You come from the world of startups. But our government is a series of competing, often sclerotic bureaucracies.

It's important for whoever has the role to go in with the expectation that the federal government is the opposite of a startup. To expect it to be agile is just ludicrously unrealistic.

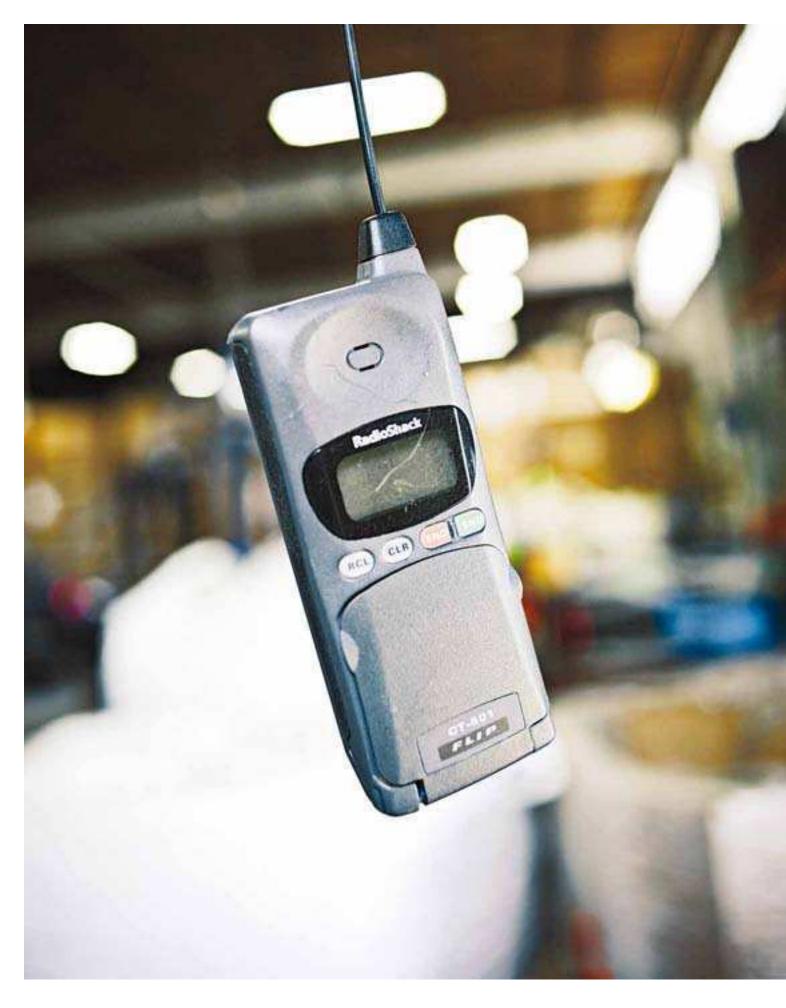
So who's on your shortlist?

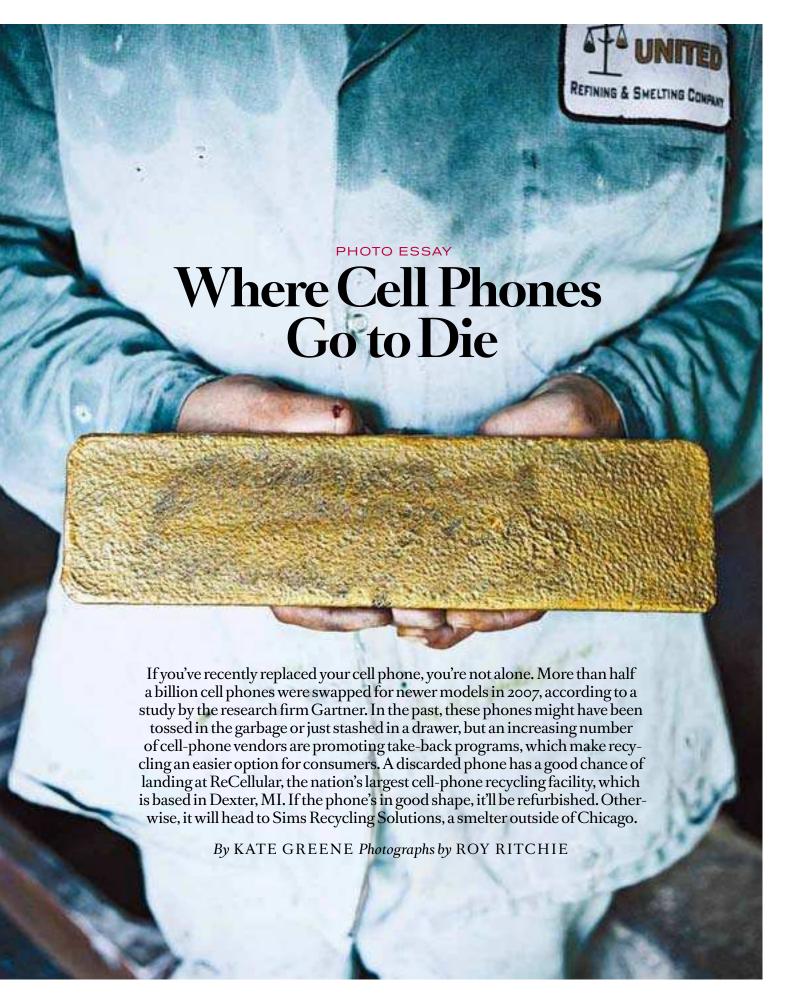
I'm a million miles away from whatever group of people will actually pick the CTO. I would like it to be someone who has some startup DNA in him or her, but who's realistic about getting things done.

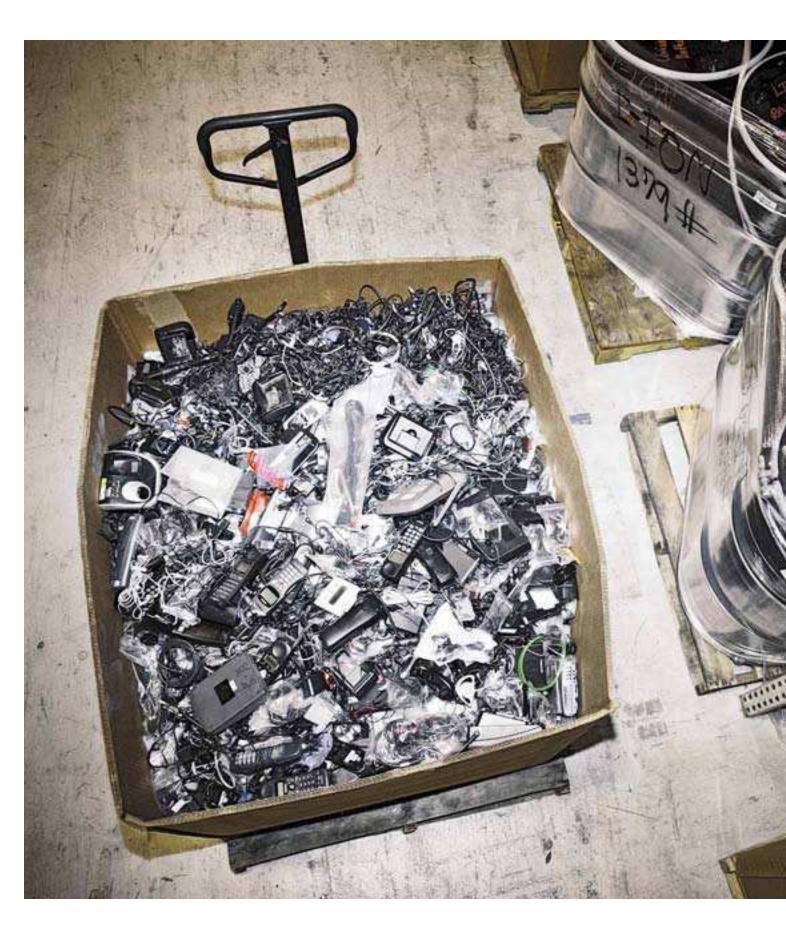
One has to ask: do you want to be CTO?

I'm interested in helping in some way, but the time to think about specifics is post-election. TR

















More than half a million phones are sorted (above) and tested (left) at ReCellular each month, says Mike Newman, a vice president at the company. Batteries are removed from the phones that don't work (top) and recycled separately. About 60 percent of the phones that arrive at ReCellular can be fixed up and sold again. Of these, 15 percent—the most commonly received models—are refurbished by ReCellular; the company sends the rest to other refurbishing sites in the United States and abroad. Newman says that a phone might come through his facility to be refurbished as many as three times.



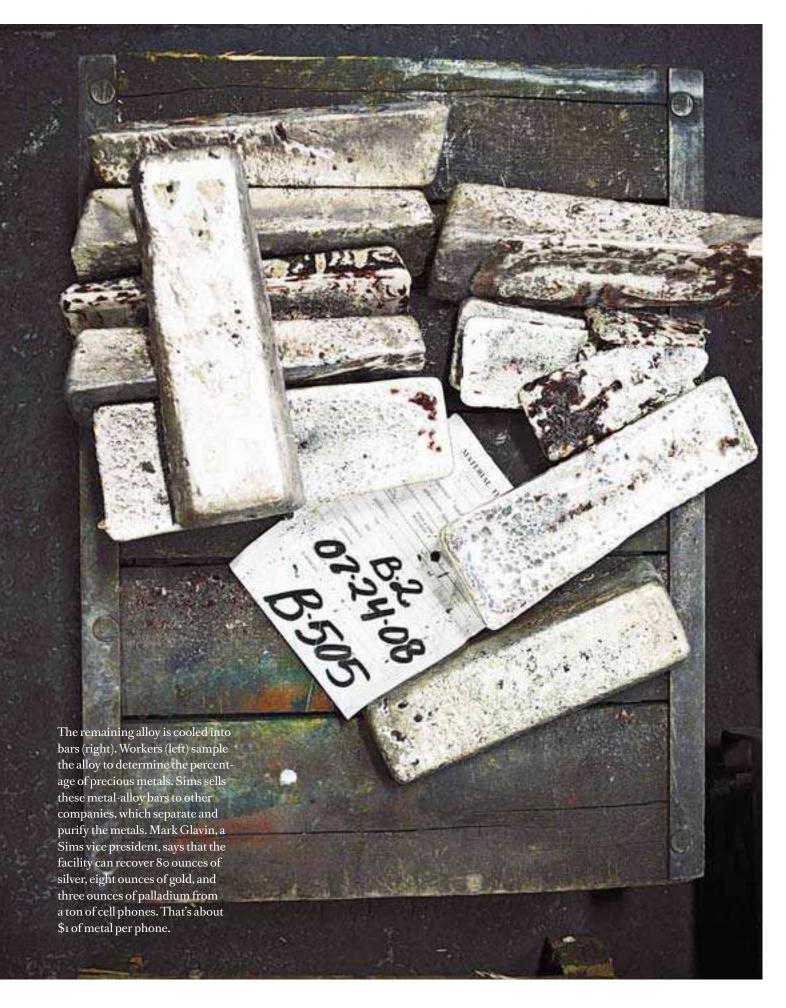


The phones that can't be saved are sent to Sims Recycling Solutions, which receives more than 30,000 pounds of them each month. When the phones arrive, they are dumped onto a conveyor belt (above and left) that deposits them in a shredder. Shards of plastic, metal, and fiberglass are spit out the other side (right). The shredded phones are heated in ovens that incinerate the plastic. What's left goes into a melting furnace to produce a metal alloy covered with a brownish layer called slag, which consists mostly of silica. The slag is removed and later sold for use in shingles and road construction.



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35 INNOVATORS UNDER 35

JB	Konrad	Dries	Jeffrey	Donhee	Jack	Stefanus
Straubel	Hochedlinger	Buytaert	Karp	Ham	Dorsey	Du Toit
p. 50	p. 54	p. 54	p. 55	p. 56	p. 56	p. 57
Kostya	Peter L.	Aimée	Johnny	Xian-Sheng	Julia	Jenova
Novoselov	Corsell	Rose	Lee	Hua	Greer	Chen
p. 58	p. 58	p. 60	p. 62	p. 63	p. 64	p. 64
Theodore	Nicholas	Farinaz	Meredith	Eric		Michelle
Betley	Fang	Koushanfar	Ringel Morris	Wilhelm		Chang
p. 64	p. 66	p. 67	p. 67	p. 68		p. 69
Adam		Hossam	Joo Chuan	Ronggui	Christopher	Milica
Smith		Haick	Tong	Yang	Chang	Radisic
p. 69		p. 70	p. 70	p. 71	p. 72	p. 72
Andrew Ng p. 72	Sundar lyer p. 73		Т	R	3	5
Robert	Ric	Tanzeem	Seth	Bilal	Blaise Agüera	Martin
Wood	Fulop	Choudhury	Hallem	Shafi	y Arcas	Burke
p. 74	p. 74	p. 74	p. 75	p. 76	p. 77	p. 77

AT TECHNOLOGY REVIEW, selecting the TR35—our annual list of leading young innovators—always produces equal parts excitement and frustration. Selecting just 35 men and women, all under the age of 35, from a pool of more than 300 outstanding nominees is always difficult, but learning of the remarkable technologies they've invented and discoveries they've made so early in their careers is awe inspiring. We select the TR35 on the basis of their accomplishments as researchers, inventors, or entrepreneurs. To help evaluate the importance and impact of these accomplishments, we rely on our panel of experts (see page 52 for a list of this year's judges).

This year's group of innovators is transforming everything from the cars we drive to the way we use computers, treat heart attacks, and manage our e-mail. Several are working on ways to conserve and more efficiently produce energy, others to help us collaborate and connect; still others are taking advantage of the body's capacity to heal itself. As they fight disease, global warming, and the complexity of life in the 21st century, the TR35 aspire to truly improve the world. —*The Editors*

WWW.TECHNOLOGYREVIEW.COM TR35 49





■ INNOVATOR OF THE YEAR

JB Straubel, 32

Tesla Motors Engineering electric sports cars

s he pulls away from the headquarters of Tesla Motors in San Carlos, CA, JB Straubel apologizes for the condition of the car. The outside looks fine, a gleaming orange. But inside, instruments dangle from the dashboard. A message scrawled on blue masking tape warns that the passenger's-side air bag is disabled. A bell chimes mysteriously. The car had been shipped to England and subjected to vibration tests designed to "shake it apart and kill it," Straubel says. Now it's an engineering car—one Straubel, the company's chief technology officer, feels comfortable drilling holes in and bolting prototype hardware to. "It's pretty much already written off," he says. "But it's also the fastest car in our fleet at the moment."

He punctuates the sentence by hitting the accelerator. Straubel looks remarkably calm as the car surges forward, pressing him into the seat. From a dead stop at the on-ramp, it takes just a few seconds to overtake the vehicles on California's Highway 101. In sports cars, this kind of acceleration is ordinarily accompanied by rapid-fire shifting, but Straubel never takes his hands off the steering wheel. Powered by batteries and an electric motor, the Tesla Roadster isn't bound by the limits of old-fashioned gas-burning engines. At its top speed of over 120 miles per hour, it remains in its first and only gear.

Straubel doesn't come close to 120 miles per hour today. Since the car can accelerate to 60 miles per hour from a stop in just under four seconds, "you get caught up to traffic pretty fast," he says, easing off the accelerator. "It kind of spoils you." It's easy to see why this powerful alternative to gas-guzzling internal-combustion engines (see Hack, p. 102) has generated such remarkable excitement.

Straubel, more than anyone else, is responsible for the car's impressive acceleration. The Roadster is the first production model from Tesla, which was founded to mass-produce high-performance electric cars. The car's carbon-fiber exterior and aluminum frame, which make it visually appealing but keep it light, are based on designs from British automaker Lotus. Straubel and his hand-picked team, however, engineered the car's brains, muscles, and guts—the electronic controls, electric motor, and battery pack that enable the Roadster to beat many of even the quickest gas-powered cars off the starting line.

Electric cars are best known for their environmental benefits: they produce no harmful emissions, and they're so efficient that they reduce total carbon emissions even if the electricity used to recharge them comes from power plants that burn fossil fuels. But Straubel's achievements capitalize on another, less appreciated advantage. Gas engines deliver their peak torque—the key to acceleration—only within a limited range of engine speeds. Keeping the engine in its optimal range requires a convoluted system of gears and clutches, and acceleration is still compromised. Electric motors, however, deliver maximum torque from a standstill up through thousands of revolutions per minute. That makes it possible to use a transmission with just one or two speeds-and it makes electric cars more responsive than gas-powered ones. Yet most electric vehicles haven't reaped the full benefit of their torque advantage, says Marc Tarpenning, one of Tesla's founders. That's because they have typically been underpowered, partly in an effort to make them as inexpensive as possible. Straubel set out to change that.

During his early days at Tesla, the company licensed a number of technologies from AC Propulsion, a small company that had pieced together a prototype electric car with acceleration similar to the Roadster's. Tesla's founders decided to use AC Propulsion's parts to produce their own prototype. But those parts were "ruinously expensive," Tarpenning says, "and no two were alike." Straubel has since reëngineered almost every one of them.

It was soon clear that the extreme torque provided by electric motors can be a problem, especially in a high-powered car. Without a well-tuned motor controller, the torque can jerk the driver around, says Andrew Baglino, one of the engineers Straubel hired. What's more, the complex interplay between the driver's application of the accelerator, the conditions of the road, and the electronic characteristics of the battery and motor can have unexpected consequences.

AC Propulsion's controller was "a hokey analog system-messy circuitry that was 20 years old," Straubel says. As he and his team worked to develop a production-ready car, they found that one controller would work well while another would inexplicably fail. 'We'd debug it for weeks trying to figure out what the hell was different, and we never could," Straubel says. The unreliable controllers would sometimes cause the motor to jitter. Worse, at times all power would cut out—once, as the car was hurtling down the highway.

Straubel reasoned that a digital control system would solve these problems. Switching to digital would require starting from scratch, but he was sure the new system would both improve performance and speed development. Yet the decision was made to stick with the analog system, in the hope that its kinks could be worked out.

Undeterred, Straubel put Baglino to work on what appeared to be a side project: designing test equipment that put the company's motors and batteries through the paces of simulated driving cycles. This equipment was to have digital controls, which Straubel intended to translate into a digital controller for the car.

Meanwhile, the engineers continued to painstakingly debug the analog system. "It felt silly to be solving problems that we knew we were trying to make obsolete," Straubel says.

After months of working on the digital test equipment, the engineers had learned enough to design a prototype digital controller. It worked, and soon the messy analog system was gone. The jittering and jerking gave way to a digitally controlled, reliably smooth ride-and a car that was, incidentally, far more responsive.

The Roadster's exceptional motor, too, is a tribute to Straubel's persistence. Tesla initially used a third-party transmission that included two gears-one to accelerate from a stop and the other to reach high speeds. The system gave the Roadster a top speed of more than 120 miles an hour. However, the shifting system routinely wore out after just a couple of thousand miles. So Straubel

2008 TR35 **JUDGES**

Angela Belcher*

Professor of materials science and engineering and of biological engineering,

David Berry

Principal, Flagship Ventures J. J. Cadiz* Program manager,

Incubation Group, Microsoft Research George Candea*

Assistant professor of computer and communication sciences, École Polytechnique Fédérale de Lausanne

Yet-Ming Chiang

Professor of ceramics,

George Daley

Associate professor of biological chemistry and molecular pharmacology, Harvard Medical School

Drew Endy

Assistant professor of biological engineering,

Claire Gmachl*

Associate professor of electrical engineering, Princeton University Irene Greif

IBM Fellow; director, Collaborative User Experience Group, IBM Watson Research Center

J. Karl Hedrick

Professor of mechanical engineering; director, Vehicle Dynamics Lab, University of California, Rerkeley

Brian Hughes

Chairman and product engineer, HBN Shoe

Steven Koonin

Chief scientist, Håkon Wium Lie*

Chief technology officer, Opera Software Nick McKeown Associate professor of electrical engineering and

computer science.

Stanford University

and applied science; associate director. Yale Institute for Nanoscience and Quantum Engineering,

Kevin Rose'

Digg

Chad Mirkin*

Professor of chemistry, of medicine, and of material sciences and engineering; director, International Institute for Nanotechnology, Northwestern University

Dipankar Raychaudhuri Professor of electrical and

computer engineering; director, Winlab, Rutgers University

Mark Reed Professor of engineering

Yale University

Founder and chief architect,

Joshua Schachter'

Founder, Del.icio.us

Bjarne Stroustrup

Professor of computer science, Texas A&M University

Lisa Su*

Chief technology officer, Freescale Semiconductor **Edwin Thomas**

Professor of materials science and engineering

James M. Tour Professor of chemistry, of computer science, and of mechanical engineering and materials science.

Rice University

Sophie Vandebroek

Chief technology officer; president, Xerox Innovation Group, Xerox

David Victor

Professor of law: director. Program on Energy and Sustainable Development, Stanford University

Jennifer West*

Professor of bioengineering, Rice University

Ben Zhao*

Assistant professor of computer science, University of California, Santa Barbara

*Past TR100/TR35 honoree

TESLA ROADSTER SPECS Style Two-seat, open-top, rear-drive roadster Drivetrain Electric motor with single-speed transmission Motor Three-phase, four-pole electric motor, 248-horsepower peak (185 kilowatts), redline 13,000 revolutions per minute, regenerative engine braking Chassis Bonded extruded aluminum with four-wheel wishbone suspension **Brakes** Four-wheel disc brakes with antilock Acceleration 0 to 60 miles per hour in less than four seconds Top speed 125 miles per hour Range About 220 miles 100,000 miles **Battery life** Energy storage system Custom microprocessor-controlled lithium-ion battery pack Full charge About 3.5 hours

found a way to replace it with a single-speed gearbox. Early on, Straubel and his team had redesigned the patterned metal plates and wire coils at the heart of electric motors to improve both efficiency and torque. But the electronics feeding power from the battery to the motor still limited its output. To exploit the added torque, Straubel added higher-performance transistors and retooled the electrical connections between the motor and the gearbox. These changes increased the torque that the motor could deliver at low speeds and allowed the engineers to use a single-speed transmission without sacrificing either acceleration or maximum speed.

But Straubel's most notable contribution may have been to keep the car from bursting into flames. Tesla's founders decided from the start to power the car with lightweight lithium-ion batteries of the type used in laptops, and they knew they had their work cut out for them. If lithium-ion cells are pierced, crushed, overcharged, or overheated, they can combust. The challenge was even greater because the individual cells were small: it would take 6,831 of them to give the car a decent range. All those cells would have to be wired together into an ensemble that was durable but allowed the charging and temperature of each cell to be carefully controlled.

This was fine with Straubel, who had been building electric vehicles since before he was old enough to drive and had long wanted to make a laptop-battery-powered car. Under his direction, all those goals were reached. But along the way, the team discovered that in some (extremely rare) cases, manufacturing defects within a cell could cause it to heat up and catch fire without any outside

cause. (This problem led to the recall of millions of laptop batteries in 2006.) Using computer models, Straubel found that if any one of the 6,831 cells caught fire, it could set off its neighbors, starting a chain reaction that could destroy the battery pack and turn the car into a smoldering wreck. Tarpenning asked at the time, "So, JB, what's going to happen to our energy storage system?"

As it turned out, the solution was already at hand, largely because of an argument Straubel had won early in the development of the battery pack. The car's initial design called for air cooling to control the temperature of the batteries and extend their lifetime. But Straubel quickly realized that that approach wouldn't provide the necessary control.

"We had a lot of heated discussions about what direction we should go," Straubel says. But his cool-headed logic, along with some hard figures, won the day. The resulting liquid cooling system—a network of tubes running past almost every cell in the pack—also offered a solution to the problem of the spontaneously combusting cell. With slight improvements, the system was able to evacuate the heat from a flaming cell so quickly that it couldn't set off its neighbors. As with the digital controller, Straubel had been able to find a solution, even if it meant going against the grain.

Tesla began shipping Roadsters this year; the first four were delivered by June. Richard Chen, a former Google product manager who hopes to have his car by Christmas, mailed in a \$100,000 check long before the production car existed, and before the company had even announced a price. His excitement is not unique: the car, which has a base price of \$109,000, is back-ordered for at least a year.

Its success may have an impact well beyond Tesla's bottom line. Bob Lutz, GM's vice chairman, was quoted in *Newsweek* as saying that the Roadster was a deciding factor in GM's decision to return to electric cars after abandoning them several years ago. If a Silicon Valley startup can do it, he reasoned, why can't GM? What's more, the Roadster may be changing the image of electric cars and increasing their chances for success. People such as Chen, who got to test-drive the car before finalizing his purchase, are buying it not to save the planet (though the green credentials are a nice side benefit, Chen says) but simply because it's so much fun to drive.

These days, Straubel is focusing on improving the Roadster and engineering a sedan to open up a new, wider market for the company. And tentative plans are in the works for a small car, such as an electric version of Daimler's tiny, inexpensive Smart car.

All that means long days for Straubel, and part of what keeps him going is the belief that he's doing something important: finding a way to deal with the world's energy woes. But he seems most driven by pure enjoyment. That's clear enough when he's behind the wheel of the latest version of the Roadster, whose new electronics can deliver far more power than the first version had. "It's amazing what a few hundred more amps can do," he says, laughing, after a burst of acceleration. "It's fun, huh?" — Kevin Bullis

WWW.TECHNOLOGYREVIEW.COM TR35 53

BIOTECHNOLOGY

KONRAD HOCHEDLINGER, 32

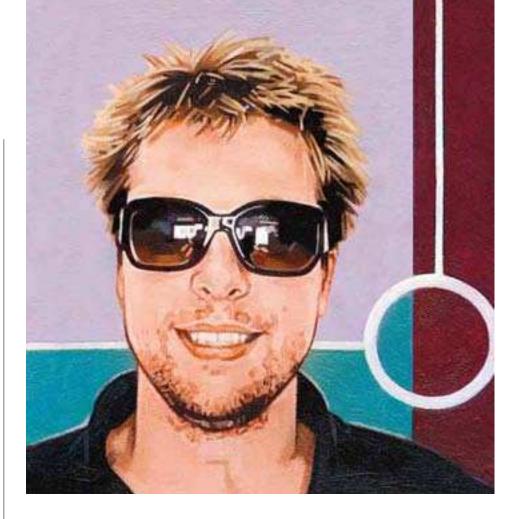
Harvard Medical School Turning adult cells into stem cells

IN 2006, scientists demonstrated that inserting four embryonic genes into mouse skin cells induced a small fraction of them to look and behave like embryonic stem cells. The technique promised to eliminate the need to destroy embryos to generate stem cells. But the first cells made this way were not completely "reprogrammed".

Konrad Hochedlinger, an assistant professor of medicine, found a simple way to improve the technique. Working with mouse cells, he initiated the reprogramming process by means of the same four genes that previous scientists had used. But he used a different gene to identify the cells that had been successfully reprogrammed; cells in which that gene is active turn out to look and act more like embryonic stem cells than those made previously. The technique offers a way around the controversies that have slowed embryonic-stem-cell research, which has the potential to help scientists understand certain diseases and, eventually, replace diseased or damaged tissue. - Emily Singer

The patterns in which methyl groups attach to DNA in Hochedlinger's reprogrammed cells (right) match those seen in embryonic stem cells (left) more closely than those seen in adult cells (middle).





INTERNET

Dries Buytaert, 29

Simple, flexible Web publishing

The Internet has made publishing on a global scale almost effortless. That's the rhetoric, anyway. The truth is more complicated, because the Internet provides only a means of distribution; a wouldbe publisher still needs a publishing tool. A decade ago, people who wanted such a tool had three choices, all bad: a cheap but inflexible system, a versatile but expensive one, or one written from scratch. What was needed was something in the middle, requiring neither enormous expense nor months of development-not a single application, but a platform for creating custom publishing environments. For tens of thousands of sites and millions of users, that something is Drupal.

Created as an open-source project by Dries Buytaert, Drupal is a free content management framework—a tool for building customized websites quickly and easily, without sacrificing features or stability. Site owners can choose from a list of possible features: they might, say, want to publish articles, offer each user a profile and a blog, or allow users to vote or comment on content. All these features are optional, and most are independent of the others.

With Drupal's high degree of individualization, users can escape cookie-cutter tools without investing in completely custom-made creations, which can be time-consuming, costly, and hard to maintain. The Howard Dean presidential campaign used Drupal in 2004, and today it's used by Greenpeace U.K., the humor magazine the Onion, Nike's Beijing Olympics site, and MTV U.K., among many others.

The diversity of its users has led to many improvements, Buytaert says: "The size, passion, and velocity of the Drupal community makes incredible things happen."

There are tens of thousands of active Drupal installations worldwide. Thousands of developers have contributed to the system's core, and more than 2,000 plug-ins have been added by outside contributors.

Buytaert began the work that became Drupal in 2000, when he was an undergraduate at the University of Antwerp. He had a news site called Drop.org, and he needed an internal message board to host discussions. After reviewing the existing options for flexible message boards, Buytaert decided he could write a better version from scratch.

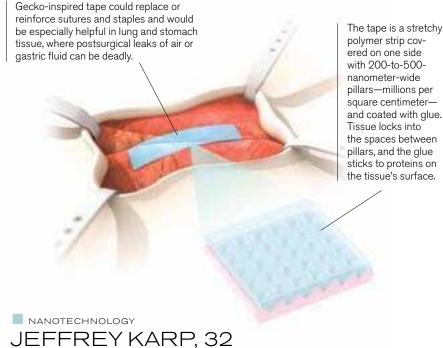
The original version of Drupal (its name derives from the Dutch for *droplet*) worked well enough to attract additional users, who proposed new features. Within a year, Buytaert decided to make the project open source. He released the code in January 2001 as version 1.0.

Since open-source projects tend to attract expert users, they often lack clear user interfaces and readable documentation, making them unfriendly to mere mortals. But Buytaert understood from the beginning how important usability is to the cycle of improvement, adoption, and more improvement that drives the development of open-source software. The core Drupal installation comes with voluminous help files. The central team regularly polls users as well as developers (which is unusual in an open-source project) to decide what to improve next. The process reveals not just features to add, but ones to remove, and ways to make existing features easier to understand. For example, the project's website has been redesigned to help people new to Drupal figure out how to get up and running.

Buytaert has also founded a company, Acquia, to offer support, service, and custom development for Drupal users, especially businesses. He calls Acquia "my other full-time job" and likens it to Linux distributor Red Hat, which provides custom packaging and support for its version of the open-source operating system.

With Drupal version 7, due later this year, Buytaert hopes to include technologies that will make sites running Drupal part of the Semantic Web, Tim Berners-Lee's vision for making online data understandable to machines as well as people. If Drupal hosts a website containing a company's Securities and Exchange Commission profile, for example, other

sites could access just the third-quarter revenues, without having to retrieve the whole profile. The goal of sharing data in smaller, better-defined chunks is to make Drupal a key part of the growing ecosystem of websites that share structured data. If this effort succeeds, it will ensure Drupal's continued relevance to the stilldeveloping Web. -Clay Shirky



Harvard-MIT Division of Health Sciences and Technology Gecko-inspired surgical tape

BIOENGINEER Jeffrey Karp may finally have found a noninvasive alternative to the sutures and staples that have long been a mainstay of surgery and emergency medicine. Using a biodegradable elastic polymer, Karp and his colleagues have created a surgical tape that is covered with nanoscale pillars akin to the gripping structures on geckos' feet. Coated with a sugar-based glue, the tape securely closes a surgical incision and then degrades completely over time.

Karp can adapt the polymer to suit different applications: a patch for the heart, for example, would need to be more stretchable than one for the liver, while one to close cuts on the skin would need a different pattern of pillars. The polymer can also release drugs to help tissue heal. More than two dozen companies are interested in licensing the tape, which has shown promise in early animal tests. If all goes well, gecko tape could enter clinical trials within five years. – *Katherine Bourzac*

Donhee Ham, 34

Harvard University
Portable nuclear magnetic resonance

COMBINED with specially engineered magnetic nanoparticles, nuclear magnetic resonance (NMR) is a potentially fast and easy way to spot cancer, bacteria, and viruses in blood samples. But current NMR systems use large and expensive magnets, making them impractical for, say, widespread cancer screening and other routine diagnostic tests. So Donhee Ham, an associate professor of the natural sciences, built a system that is only slightly bigger than a cell phone and weighs less than two kilograms—yet is 60 times as sensitive as existing 120-kilogram tabletop systems that could cost 70 times as much. The key is a silicon radio-frequency chip that compensates for the low-quality signal caused by using a smaller magnet. The system has been tested in collaboration with Massachusetts General Hospital, and companies have expressed interest in incorporating Ham's technology into diagnostic instruments. - Brittany Sauser





JACK DORSEY, 31 Twitter Personal updates made simple

IN 2006, Jack Dorsey created Twitter so that he could let friends and family know what he was doing, wherever he—or they—might be. Today more than two million people use it to send out 140-character-or-fewer updates, called "tweets," through Twitter's website or by text message over mobile devices. Dorsey's ethos of simplicity shapes everything about Twitter, from the application itself to the company's San Francisco offices (see "Home Tweet Home," July/August 2008). Twitter's

popularity has given rise to an entire ecosystem of applications. Yet Dorsey, cofounder and now CEO of the bemusing microblogging service, is secretive about how Twitter will ever make money; critics say that's because its executives have no idea. What's not a secret is that Twitter has had difficulties supporting its growing band of obsessives: in recent months, twitterers have been frequently confronted by error screens bearing messages such as "Twitter is stressing out a bit right now."

Jason Pontin, *TR*'s editor in chief, recently chatted with Dorsey about these and other issues using Twitter's @reply function, which directs a public message to a particular user.

jason_pontin @jack Explain Twitter.

jack @jason_pontin Twitter is a real-time repository of state for people, events, & things. A personal news wire of sorts.

jason_pontin @jack I twitter every day. But whenever I explain it to people who've not, they are uncomprehending or angry. Why?

jack @jason_pontin People have to discover value for themselves. Especially w/ something as simple & subtle as Twitter. It's what you make of it.

jason_pontin @jack Critics say that tweets are trivial. Is that missing the point?



jack @jason_pontin It depends on the context the recipient brings. There's a universe in the smallest, most "trivial" details of one's life.

jason_pontin @jack Even people who love Twitter are frustrated by the service. It's broken far too often to feel reliable

jack @jason_pontin We love what we're building & we hate to see it suffer. Our goal is to make it reliable enough to be trusted as a public good.

jason_pontin @jack Twitter also seems to lack basic stuff. I can't organize my followers intelligently. Or search very well. When will Twitter grow up?

jack @jason_pontin Unfortunately, we've neglected the user experience to focus on stability of the foundation. We have designs to put this right.

jason pontin @jack You recently got \$15 million from Spark Capital and Bezos Expeditions. Will you buy some servers and infrastructure with that?

jack @jason_pontin I can't confirm the number, but I can confirm we'll make the money work for our users (20 of whom happen to be our investors)!

jason_pontin @jack What's Twitter's business model?

jack @jason_pontin We're building what we love. While we have many ideas for sustainable revenue, Twitter's will emerge naturally from our work.

jason_pontin @jack Sometimes it sounds like your monetization plan is: let's get acquired by a communications company.

jack @jason_pontin We're not focused on answering that question. We're determined to build a solid platform and service we can take all the way.



SOFTWARE **STEFANUS** DU TOIT, 25 RapidMind Programming for parallel processors

PROBLEM: As the ever-shrinking computer chip begins to run into fundamental physical limits, designers have begun building multiple processor "cores" onto each chip to improve performance. But writing software that can run in parallel on multiple cores is complicated and time consuming, and few programmers have the expertise to do it. As a result, most of the capacity on a multicore chip goes to waste.

SOLUTION: Stefanus Du Toit has created software that makes it easier to translate traditional serial programs into parallel programs. He began its development as a graduate student at the University of Waterloo, in Ontario: in 2004 he cofounded RapidMind, in Waterloo, to commercialize it. The company has raised \$10 million and partners with Advanced Micro Devices, Hewlett-Packard, IBM, and others.

With RapidMind's technology, programmers write software in C++ as usual; then they use a special interface to specify which parts of the program should be parallelized. The platform automatically parcels out those tasks among the cores. It builds code into the final program that manages workload, ensuring that each core is fully utilized and preventing errors such as one task's stalling while it waits for another to finish. Finally, the platform optimizes the program to run on a particular chip-say, an eight-core chip from Intel. The finished program runs more efficiently; in one example, an imageprocessing application rewritten with the RapidMind platform ran 10 times as quickly on eight cores as on a single processor. -Neil Savage





NANOTECHNOLOGY

Kostya Novoselov, 34

University of Manchester Two-dimensional transistors

n 2004, Manchester University fellow ▲ Kostya Novoselov discovered graphene, a fundamentally new molecule that may revolutionize computing. Physicists had previously speculated about the material, theorizing that it could be made into transistors more than a hundred times as fast as today's silicon devices. But until Novoselov found and tested it, some thought the essentially two-dimensional material would be unstable.

To make graphene, which is a mesh of carbon one atom thick. Novoselov shaves small flakes of graphite, similar to that found in pencils, onto adhesive tape. He then folds the tape over and pulls it apart, splitting the graphite into two thinner flakes. He repeats the process until he has a one-atom-thick sheet.

Since the discovery, Novoselov has made a fast, low-power graphene transistor using techniques from the semiconductor industry. Because they conduct electrons so rapidly, such transistors could lead to faster computers and to specialized communications and imaging technologies such as terahertz-wave imaging, which could be used for medical tests or security applications. A slew of academic and corporate labs have begun working on graphene, but Novoselov and other scientists are still researching practical techniques for making large sheets of it. For now, Novoselov's pencil-and-tape method is standard. -Katherine Bourzac

ENERGY PETER L. CORSELL, 30 GridPoint Making the electric grid smart

IN TODAY'S power grid, a steady but essentially passive flow of electricity links power plants, distribution systems, and consumers. It is a "dumb, inefficient system," says Peter L. Corsell, founder and CEO of GridPoint; in order to meet peak demand, power plants must be able to generate twice as much electricity as is typically needed. So Corsell has created energy management software that, combined with hardware from GridPoint and others. allows utilities to better balance power generation and electricity demands, increasing both efficiency and reliability.

GridPoint's software allows consumers to use a personalized Web portal to set limits on electricity consumption. Using a small computer attached to a home's circuit box, utilities then measure energy consumption and control appliances such as water heaters and thermostats. "Consumers should be able to buy 74° and the utility company then sells them 74°," says Corsell. In addition to helping people conserve energy and reduce their bills, the system makes it simpler to integrate renewable energy sources such as solar cells and wind turbines into the grid.

Corsell has raised \$102 million, and utilities will begin deploying the technology within the next year. For instance, Xcel Energy, a Minneapolis-based utility, has selected GridPoint's platform for its power grid project in Boulder, CO. –Brittany Sauser



ONLINE ENERGY MANAGEMENT

A Web portal provides consumers with detailed usage data and allows them to set individual limits on power consumption. For example, homeowners could save money by letting the system automatically adjust their thermostats within a range of a few degrees.

PLUG-IN HYBRID **ELECTRIC VEHICLES**

Regardless of when consumers plug in their electric vehicles, the system can charge the cars during off-peak periods in exchange for reduced electricity rates.

ENERGY STORAGE DEVICES

RENEWABLE ENERGY SOURCES GridPoint's platform allows energy from solar panels, wind turbines, and fuel cells to be captured and stored at individual homes and then fed into the power grid when demand is high.

Advanced batteries can be used to store energy during off-peak hours for discharge during peak periods. They can also provide automatic backup power.

CONTROL INTERFACE FOR UTILITIES

Utility companies can use a Web-based interface to obtain information on energy delivery, capacity, and availability and to control devices that measure and manage how much power is being used. Alternatively, the same capabilities can be integrated into utilities' own systems.

LOAD MEASUREMENT AND CONTROL

A small, specialized computer is connected to the circuit box and to the online energy management systems used by consumers and utilities. The device measures the electricity used by water heaters, air conditioners, and other appliances and controls energy usage according to the consumer's personal profile.



HUMANITARIAN OF THE YEAR

Aimée Rose, 34

ICx Technologies

Ultrasensitive detectors to sniff out explosives

he detonation of a single pound of explosives hidden aboard an airliner flying over Lockerbie, Scotland, in 1988 was, for many, a turning point in understanding how vulnerable the public is to the actions of terrorists. The bombing of Pan Am Flight 103 and the deaths of its 259 passengers (and 11 people on the ground in Lockerbie) set off a behindthe-scenes, government-funded race to find better ways to detect explosives. That race acquired additional urgency after the September 11 attacks, and it became frantic when IEDs-improvised explosive devices-started killing U.S. soldiers in Afghanistan and Iraq. Now, 20 years after the Lockerbie bombing, Aimée Rose is playing a key role in creating and commercializing ultrasensitive detectors that help to protect us against explosives.

Largely because of Rose's work as a scientist, engineer, and research manager, new types of portable chemical "sniffers" are now widely used to detect trace amounts of explosives in the air. These sensitive instruments are already detecting land mines, IEDs, liquid explosives in sealed containers, and even people who have been in contact with explosives. "You can pull aside as many passengers in security lines as you want, but if you don't have the ability to detect explosives on them, it won't do much good," says Susan Martonosi, an operations researcher at Harvey Mudd College in Claremont, CA, who studies homeland security. "That has long been a weakness in the system."

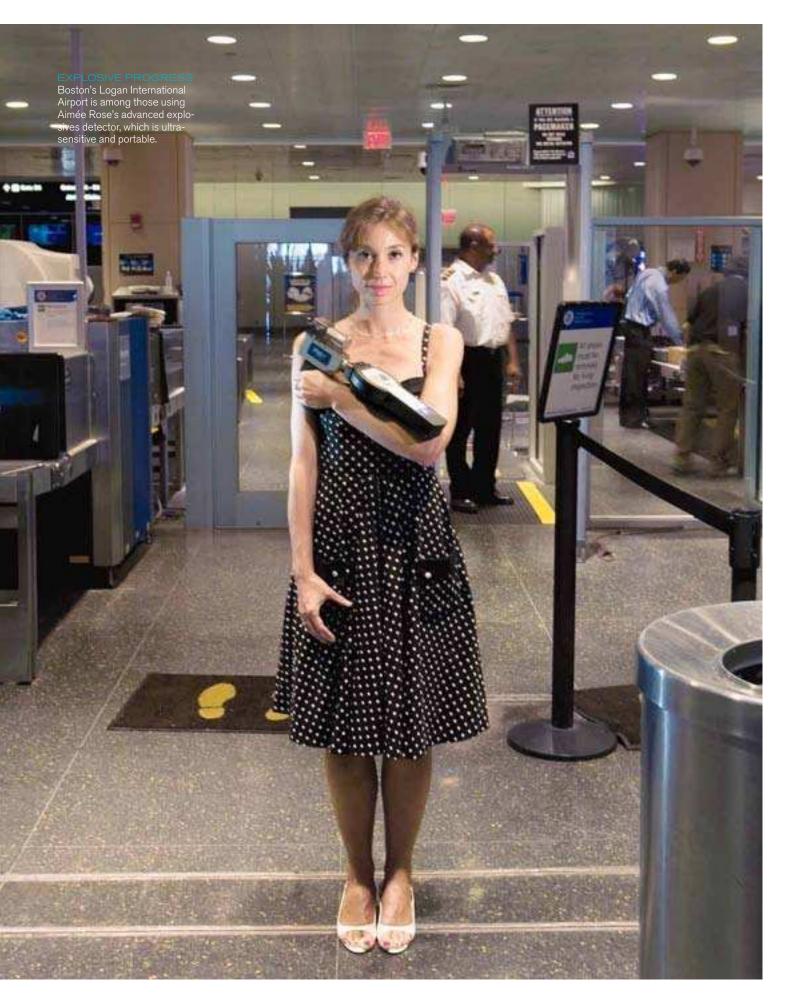
Rose's chemical sniffers are part of a growing effort to develop explosives detectors that go beyond x-ray scanners, the large instruments commonly found in airports. Whereas x-ray scanners look for the characteristic shapes of bombs and can easily be fooled by tricks such as embedding explosives in electronic devices, the new kinds of detectors find explosives by picking out their distinctive chemical composition. But it's a complex problem, because those chemical signatures are diverse and often extremely faint. (Trained dogs that sniff out the vapor given off by explosives are still the most reliable and sensitive bomb detectors, but they're in short supply.) Airports have largely relied on ion-mobility spectrometers that examine the chemicals in either

swabs from luggage or puffs of air blown at passengers in sealed chambers. Swabs can easily miss a well-hidden explosive, though, and analyses of air samples are frequently thrown off by dirt, dust, and other contaminants. Rose's technology, on the other hand, is the first explosives detector that matches the sensitivity of dogs. What's more, it's handheld and easy to use, and it's the only device capable of detecting the hidden liquid explosives that have become a serious security concern in the past few years.

Rose was in college when she first tackled the problem of detecting chemicals and toxic materials. "I wanted an opportunity to put something in people's hands that could affect their lives and maybe make them safer," she says. She was planning to do her graduate work in materials science at Harvard, until she was awakened at six one morning by a phone call from a stranger who spoke in long, enthusiastic rushes. "It was as if he couldn't get the words out fast enough," she recalls. "I was half asleep and very irritated." After a few minutes she was able to make out that the man was a chemistry professor who had just set up shop at MIT, complete with a new grant from the U.S. Defense Advanced Research Projects Agency to develop a chemical sensor capable of detecting land mines. He had seen her application to MIT, an application that everyone else in the department had ignored; would she consider visiting?

She did visit-after all, she was going be in town anyway-and it didn't take long for the professor, Timothy Swager, to persuade her to sign on as a graduate student in his lab. For one thing, landmine detection seemed like exactly the sort of project she had been looking for. "The poorest countries in the world are littered with land mines, and that hurts some of the most needy people on the planet," she says. "It's a very motivating cause."

When Rose joined Swager's lab, he was synthesizing polymers that fluoresce when exposed to certain wavelengths of light. If a certain type of smaller molecule-say, one found in an explosive such as TNT-binds with one of these polymer chains at any location, the whole polymer stops glowing. The sudden loss of fluorescence is measurable even if just a single target molecule



has bound to the chain, so the polymer can serve as the heart of an extremely sensitive detector. "The polymer acts like a string of Christmas tree lights, where if you knock one out, the whole string shuts down," Rose explains. "The fact that you have a much larger molecule responding means you get a much larger signal, which means you have much greater sensitivities." Tweaking the composition of a polymer could enable it to detect different sorts of molecules. For Swager, Rose, and the rest of the team, the goal was to get the polymers to detect the tiny amount of vaporized explosive drifting in the air immediately above a buried land mine.

Swager, now the head of the chemistry department at MIT, says Rose's contributions were critical to the team's success in using the polymers in ultrasensitive detectors. First, he says, Rose added to the researchers' theoretical understanding of how the polymers respond to light. Then she figured out how to employ that insight to develop polymers that fluoresce more brightly and are thus more easily monitored in a working device.

Still, progress with the polymers came slowly. "We were trying to take what a chemist does with a lot of equipment and boiling beakers on a bench, and make it so it could be embedded in a handheld device that's small, robust, and sensitive," says Rose. But in 1999 the lab successfully tested early prototypes in mock landmine fields. The potential applications would soon expand greatly in number and urgency. "I had been thinking only about making a contribution to land-mine safety, not the safety of U.S. soldiers and everyone who travels by plane," Rose says. "We weren't expecting September 11; we weren't expecting Afghanistan or Iraq; we weren't expecting terrorists to carry liquid explosives in bottles on planes."

While still a graduate student at MIT, Rose had begun to collaborate with researchers at a startup called Nomadics, which had licensed the polymer technology and had government funding to develop explosives detectors for the U.S. military. Rose completed her PhD in 2003, and in 2004, she joined Nomadics as a research scientist, helping to commercialize the technology. (ICx Technologies acquired Nomadics in 2005.) After years working on basic scientific questions, she now faced an entirely new challenge: how to use the promising advances in chemistry to make a practical working device. The polymer worked well enough in liquid in a test tube, but for use in an actual detector, it would have to be deposited as a thin film and still fluoresce brightly enough for any interruption in light output to be reliably detected.

The first product to result from the efforts of Rose and her colleagues was a handheld military explosives detector called Fido XT. Unlike conventional detectors, Fido XT can detect a few trillionths of a gram of explosive in the air; it rarely gives out a false positive signal; and it resets almost instantly (some detectors require hours after a hit). Has the device saved lives? "There are definitely success stories," says Rose. "But I can't talk about them." The military isn't keen to let the world evaluate its bombsniffing capabilities.

Rose can say that the handheld detectors are frequently deployed at security checkpoints and during patrols in Iraq and Afghanistan. Because of its extreme sensitivity, Fido XT has been particularly useful in catching bomb makers themselves: telltale explosives residues often cling to their clothes and skin. By employing the technology at traffic stops, in public places, and when checking homes in neighborhoods suspected of harboring

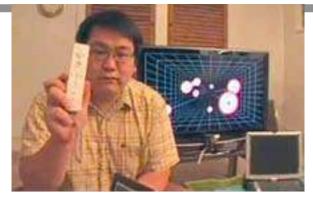
HARDWARE

JOHNNY LEE, 28

Microsoft

Streamlining human-computer interactions

WHEN the Nintendo Wii came out, most people saw a fun new way to play video games. Johnny Lee saw a surprisingly good infrared camera that could make innovative computer interfaces affordable. At the 2008 Technology, Entertainment, Design (TED) conference, he drew spontaneous applause when he demonstrated two devices he'd hacked together, which used the \$40 Wii remote and some inexpensive hardware to simulate systems that can cost thousands. The audience may not have realized that Lee had spent no more than "a few days" on each. "I have some knack," he says, "for being able to identify easy projects that have a relatively big impact"-like those at right. Having completed his PhD at Carnegie Mellon, Lee is honing that knack as a researcher in Microsoft's hardware division. - Larry Hardesty



HEAD-TRACKING VIRTUAL-REALITY DISPLAY

Using the Wii and a pair of safety glasses with infrared emitters on the stems, Lee created an inexpensive virtual-reality display that provides an astonishingly realistic 3-D view of the objects depicted on a computer screen. The Wii remote is mounted below a computer monitor, and software that Lee wrote tracks the position of the emitters by processing data from the remote's camera. Objects on-screen reorient themselves as the user's head moves. Several gaming companies are interested.

terrorists, the military hopes to identify and arrest those who have been preparing bombs. "Terrorist cells have a lot of people willing to go out and blow themselves up or plant a bomb, but they only have one or two people who are expert at making bombs," Rose says. "If you can take that person out of the chain, you can prevent hundreds of bombings."

After the release of Fido XT, Rose and ICx set their sights on airport security. Unfortunately, by 2006 the threat had changed. Terrorist plots broken up in the United Kingdom suggested that would-be airline bombers were turning to liquid explosives invisible to existing detectors-including the polymers in the company's device. But Rose's efforts to develop a thin film for the Fido XT provided another payoff: the same method proved useful in making thin films of other polymers, including those capable of detecting the new explosive threat. As a result, the company was able to rush out a new product. The Fido PaxPoint handheld detector is now deployed at airports, where it can instantly pick up molecules of the liquids wafting out of even hidden, sealed containers. "We had been looking at those substances for a few years, and when the threat came to the front burner we were able to move from first prototype to a working airport device in less than a year," Rose says. The ability to tweak the polymers to detect new types of explosives is one of the technology's biggest advantages, she adds.

That's a good thing, because terrorists are likely to keep changing the game, notes Harvey Mudd's Martonosi. "Just as our ability to detect explosives is evolving, the ability to create new explosives is evolving," she says. "It's a moving target."

-David H. Freedman



SOFTWARE
XIAN-SHENG
HUA, 34
Microsoft Research Asia
Enhancing video search

THE AMOUNT of video on the Web is growing at an incredible rate. Effectively searching online video, however, remains difficult. Microsoft researcher Xian-Sheng Hua hopes to crack the problem by teaching computers to recognize objects, scenes, events, and other elements of digital images.

Hua uses machine-learning techniques and annotated videos to train computers to automatically categorize new videos. While this general approach isn't new, Hua's system permits multiple labels for each video

segment—and relies not only on specified tags applied by experts but also on descriptions written by large numbers of grassroots Internet users. These usergenerated tags are gathered by means of online games, "pay for labeling" schemes, analysis of how people search for video, or other methods. Hua applies some automated filters to the labels to ensure their quality.

The system, which runs online, is first trained on videos tagged by experts; it's then periodically updated and retrained using the grassroots labels. This "online active learning" makes the algorithm more accurate and several times faster than previous systems; applying multiple labels to each video increases the speed further. The technology should aid searches for still images, too. Some of the techniques involved are already being incorporated into Microsoft's Live Search Video. Ultimately, Hua says, the technology should improve not only online video and image searches but also video surveillance and digital media management. - Erika Jonietz

DIGITAL WHITEBOARD

Lee re-created a \$3,000 interactive whiteboard for about \$50. Infrared light emitted by an LED bounces off the wall and strikes the Wii camera; a computer running Lee's software translates the LED's motion into digitally projected writing. More than 600,000 people have downloaded the program, which Lee gives away online.





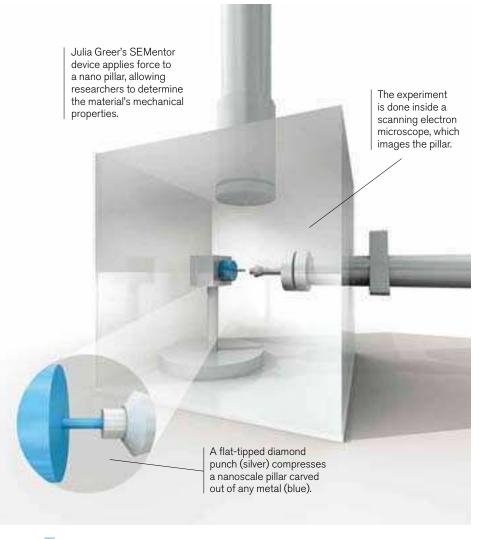
SELF-CALIBRATING PROJECTOR

If a projector is set up in a hurry, it might produce images that are lopsided or the wrong size. As part of his PhD research, Lee developed a projector that orients itself by flashing a series of patterns across a special screen and then automatically adjusts its image to fit—at various distances or angles. The system could lead to foldable projection displays for handheld devices.

¢14 CTEADICAM

As an undergrad, Lee was involved in student filmmaking. When a friend managed to procure a \$600 knockoff of a Steadicam—an expensive device that enables fluid handheld tracking shots—Lee figured out how to replicate it with just \$14 worth of parts. For people without the tools to build their own, Lee sells the devices preassembled for less than \$50 each. He's sold about 6,000 so far.





NANOTECHNOLOGY

JULIA GREER, 32

Caltech

Revealing how materials behave at the nanoscale

JULIA Greer has reinvented nanomechanics—the field that studies the mechanical properties, such as elasticity and strength, of materials at extremely small scales. These materials behave very differently from those at larger scales, and understanding the differences is essential for building reliable and durable ultrasmall devices.

Scientists have typically measured the mechanical properties of nanoscale materials by using a scanning electron microscope to capture images of an extremely sharp tip poking the surface of a thin film of the material. Greer, an assistant professor of materials science, greatly simplified and improved the process by introducing a technique that tests a nano pillar of the target material, compressing it and pulling on it in a single dimension instead of deforming an entire sheet.

Greer has used the method to confirm that metals and metal alloys are stronger at the nanoscale than at larger scales, something that researchers hadn't been able to prove before. The findings are providing engineers with the information they need to build nanoscale devices. -Kate Greene

SOFTWARE

Jenova Chen, 26

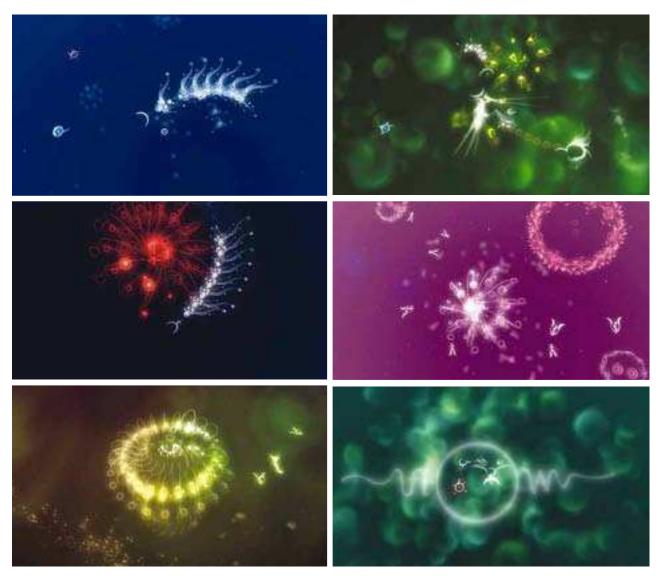
Thatgamecompany Gaming with the flow

Tenova Chen has been playing video games for 20 years, and he's desperate to see something new: right now, he says, most games focus on stimulating players by inciting aggression. "I want to expand what a video game can be," he says. So as a graduate student in interactive media at the University of Southern California, Chen looked to psychologist Mihály Csikszentmihályi's theory of "flow," which identifies a state of focus that people find enjoyable and fulfilling. Chen uses the theory's principles to design games that offer just enough challengenot so little that players become bored, not so much that they become anxious.

Chen's first effort was FlOw, a Webbased "Zen game" in which players control a sea creature that swims, eats, and evolves. After graduating in 2006, Chen cofounded Thatgamecompany to continue his work. The company released a PlayStation 3 version of FlOw in 2007; it has become one of the most downloaded games on the PlayStation Network. The next game, Flower, will be released later this year. By going with the flow, Chen may help video games reach a whole new audience. - Erica Naone

ENERGY THEODORE BETLEY, 31 Harvard University Re-creating photosynthesis

PROBLEM: Every day, plants, algae, and bacteria generate more energy than all the world's power plants, using sunlight to split water into hydrogen and oxygen and then stor-



In the dreamlike ocean of FIOw, players guide a snakelike creature through the depths. At the start, the snake must eat a tiny red-and-blue creature to enter deeper, more challenging levels; eating a tiny blue creature at any time will pull the snake back toward the surface. While exploring, players may encounter different enemies. Battling and defeating them allows the creature to evolve and gain new abilities. Players can even "unlock" new creatures and switch between them as the game progresses—changing, for example, from the snake, whose tail grows as it feeds, into a "jelly," which spins to pull smaller creatures to their doom. Though players can choose to hunt ever more powerful enemies, the game has no predefined objective. Players can focus on exploring, getting their creatures to evolve, defeating enemies, or just immersing themselves in the mysterious abyss. The free-form design aims to induce a state of "flow," engaging players without stressing them.

ing the energy in sugar molecules. Artificial photosynthesis—the process of using solar power to split water through the creation of chemical bonds, as plants do—holds promise as a clean, cheap source of hydrogen to power fuel cells. But to make the process practical, researchers must find catalysts to decrease the amount of energy needed.

SOLUTION: Most attempts at artificial photosynthesis try to split water with a single powerful chemical reaction. Theodore Betley, an assistant professor of chemistry and chemical biology, has come up with a method that mimics the multistep process plants use. He arranges small clusters of metals inside a molecular scaffold; the clusters work like a plant's photosynthetic chloroplasts, splitting water molecules in a stepwise fashion that uses less energy than one big reaction. Betley has shown that he can split water using such complexes, but his team is still searching for more-efficient catalysts. If they succeed, they will have found a valuable route to hydrogen for fuel cells by mimicking three billion years of evolution. —Lissa Harris



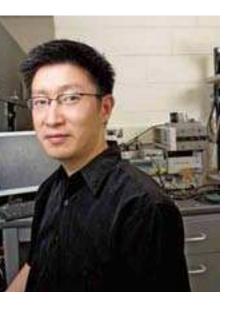
NANOTECHNOLOGY

Nicholas Fang, 33 University of Illinois at Urbana-Champaign

Superlenses for watching cells

The resolution of the best conventional light microscopeswhich, unlike higher-resolution electron microscopes, can magnify living cells-is about 400 nanometers. That's good enough to let biologists tell cells apart, but it's not good enough to let them observe the workings of organelles within the cell, such as metabolizing mitochondria, which are about 200 nanometers across. Nicholas Fang hopes that within the next few years, his technology will enable biologists to watch living cells at a resolution as fine as 15 nanometers (about the size of a protein molecule), revealing not only cell organelles but their molecular workings (see "Life Left in Light," p. 28).

Objects smaller than the wavelength of the light being shined onto them-several hundred



nanometers, in the case of visible light-scatter the light as so-called evanescent waves. These waves move in such a way that they can't be collected and redirected by conventional lenses. But in 2005 Fang developed the first optical superlens—a device that can collect evanescent waves to soup up the performance of a light microscope.

At a small workbench in his lab, Fang stamps out nanoscale silver gratings that make it possible to convert conventional light-microscope parts into superlenses. To pattern his metal structures onto fragile glass slides and other microscope parts, he starts by coating a coverslip with a thin film of silver. Separately, he carves a pattern-the inverse of the final, desired one-into a reusable stamp. He places the stamp over the coverslip and applies an electrical voltage, causing a reaction in which the silver dissolves and is pulled into the crevices of the stamp. Once the stamp is removed, the silver coating of the coverslip is left with the grating pattern.

Using this method, Fang creates intricate nanoscale patterns in about five minutes. The stamping doesn't break the delicate devices and doesn't need to be done in a clean room. And Fang says the process should be amenable to mass production of superlenses that could turn every biologist's microscope into a nanoscope.

-Katherine Bourzac







SUPER 'SCOPE

- 1. Inside a 400 °C furnace, silver and sulfide are fused under physical pressure to form a pellet.
- 2. Pellets like those in this container will be carved into superlens stamps using conventional lithography techniques.
- 3. Fang mounts a stamp on an actuator that holds it against a microscope coverslip coated in silver. Applying a voltage will dissolve the silver into the pattern on the stamp, creating a superlens.
- 4. Fang places the completed superlens on a conventional light microscope, which has been partially disassembled for modifications that will turn it into a nanoscope.



HARDWARE **FARINAZ** KOUSHANFAR. Rice University

Locking microchips to prevent piracy

PROBLEM: High-tech piracy isn't limited to illegal downloads and knockoff DVDs: there are growing, multibillion-dollar gray and black markets for the microchips that run everything from video players to high-end weapons. Unscrupulous employees in overseas foundries that produce chips for other companies can divert extra chips, made for pennies, and resell them.

SOLUTION: Farinaz Koushanfar. an assistant professor of electrical and computer engineering, has developed a way to foil hardware pirates using tiny physical variations between circuit elements on a chip-variations produced normally in the chip-manufacturing process. As small as a stray atom or two, the variations cause identical signals traveling to two such elements to arrive a few trillionths of a second apart; each chip contains hundreds of these pairs. For each pair, Koushanfar designates the first signal to arrive as a 0 and the second as a 1, creating an ID code unique to each chip. When a buyer first uses the chip, it transmits its ID to its designer over the Internet. The designer sends back a corresponding "unlock" code that makes the chip usable. Koushanfar has created prototypes of the coded chips, and several chip makers have expressed interest in the technology. - Neil Savage

INTERNET **MEREDITH** RINGEL MORRIS, 29

Microsoft Research Searching websites jointly

"I'M NOT really interested in technology for the sake of technology. I'm interested in how it helps people connect and work with other people," says Meredith Ringel Morris, a computer scientist in the Adaptive Systems and Interaction Group at Microsoft Research. Her tool SearchTogether, shown below, is a plug-in for Internet Explorer that makes it easy for groups to share the work of searching without duplicating each other's labor. Bookmarked websites appear in a frame beside the main browser window, along with users' comments and ratings. A chat window at the bottom of the screen lets users discuss results in real time if they're online simultaneously. Morris says that collaborative search combines the two activities she thinks people are most interested in doing online: communicating and gathering information. She's also working on a tool that will help groups search collaboratively when sharing one computer, which could be particularly useful in classrooms. -Erica Naone



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INTERNET

Eric **Wilhelm, 31**

Instructables Putting DIY projects online

Then Eric Wilhelm finished his PhD in mechanical engineering at MIT, he and three friends started Squid Labs, a consultancy based in Emeryville, CA, that finds fixes for clients' technical problems (how to make solar-collecting concrete, for example). But Squid Labs was also founded as a place where the colleagues could explore their own projects and ideas-funding them through their consulting jobs. In 2005, Wilhelm had an idea for a how-to website where people could share step-bystep visual instructions for original projects. The team spun the site out into its own company, and Instructables was born.

Wilhelm had hit upon the idea at the right time, just as the spirit behind open-source software began permeating other technological fields. Instructables offers its growing community of more than 300,000 registered users an easy way to document do-ityourself technology projects and share ideas with others. In that spirit, Wilhelm, who acts as the company's CEO, offers an Instructable about how to build an innovative company. -Kate Greene

"HOW TO BUILD A COMPANY" BY ERIC WILHELM



Step 1. Determine your level of risk tolerance. If it's too stressful to you to work hard for years without financial reward, the entrepreneurial life is not for you. If, however, you like to take risks and can deal with unpredictability, then starting a company is as simple as just deciding to go for it.



Step 2. Know who your team will be. The most successful startups often work well because the founders have chemistry and balance each other's talents and weaknesses. My Squid Labs cofounders and I had worked together on projects for a number of years at MIT, so we knew we were compatible.



Step 3. Determine where your company will be based. It may be fashionable to say innovation can come from anywhere, but great teams are put together in intellectual hubs, such as Boston or Silicon Valley. (We decided to open up shop in the San Francisco Bay Area after we were snowed in one night in Cambridge.)



Step 4. Figure out your company's goal. We set up Squid Labs to funnel money from consulting gigs into internal project ideas, such as this interactive musical harp. If those ideas met with success, then we would license the technology or spin it off into a separate company—à la Instructables.



Step 5. Get good at telling your story. At the MIT Media Lab, I gave, on average, one demonstration a week. Share your work, and don't worry too much about someone stealing your ideas. You are far more likely to attract partners than to give something to a competitor.



Step 6. Don't get comfortable. It's easy to let your tolerance for risk decline over time; keep it high by keeping your cost of living low. For us, this meant getting furniture and tools free from Craigslist, living in our shop, even eating from dumpsters.

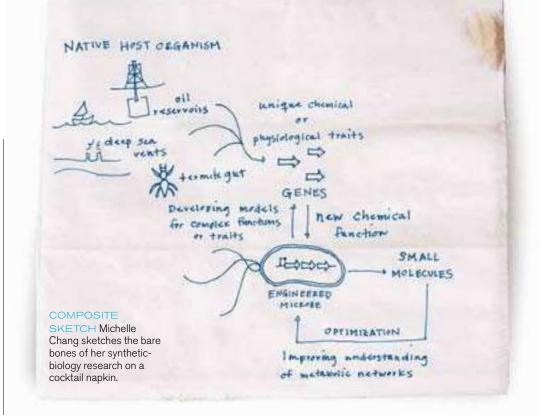
INTERNET ADAM SMITH, 23 Making sense of e-mail madness

NOT ALL e-mail is created equal. Some messages may be relevant for years, while others lose meaning within minutes. Yet e-mail in-boxes treat all messages alike. regardless of who wrote them, what they're about, or when they were sent. Adam Smith has set out to change that with Xobni, software that pulls useful information out of e-mails and contextualizes it according to sender.

Smith's goal is to help people unlock and harness the social relationships embodied in their in-boxes. The first version of Xobni (inbox spelled backwards) is a plugin for Microsoft Outlook and works only on Windows computers—but the results are remarkable.

Once it's installed, Xobni scans every e-mail and extracts information such as a sender's phone numbers, what time she is most likely to e-mail you, who else she has corresponded with, and what files the two of you have exchanged. It labels all the data with descriptive tags, which it then indexes and analyzes. When you click on a specific e-mail, it displays all the information relevant to that sender in a sidebar that runs down the right side of the Outlook window. The tags also allow Xobni to search all indexed e-mails very rapidly.

Smith and his friend Matt Brezina founded Xobni in San Francisco two years ago and have raised \$4.25 million from companies including First Round Capital and Khosla Ventures. The plug-in has received one startling endorsement: Bill Gates used it in a public demo at a Microsoft conference, even though the free download remains in beta. There



BIOTECHNOLOGY

Michelle Chang, 31

University of California, Berkeley Designing microbes to make fuels and drugs

ORGANISMS that live in exotic environments have evolved unique traits in order to survive. Michelle Chang, an assistant professor of chemistry, hijacks the chemical reactions that confer those traits, combining them in novel ways. By inserting borrowed genes into easy-to-grow microbes such as *E. coli*, she creates organisms with new abilities.

In one project, she is creating a system that takes lignin, a tough polymer abundant in agricultural waste, and breaks it into molecules that can be converted into biofuels. Chang is also developing a way to incorporate fluorine into organic molecules. Many modern drugs-Lipitor, for instance-require at least one fluorine atom per molecule to perform their functions. But fluorine is difficult to add to molecules using traditional chemistry.

While her projects have important practical applications, Chang hopes that her work will lead to basic tools for engineering organisms that can perform all kinds of reactions that are too difficult, expensive, or dangerous with traditional chemistry. -Erika Jonietz

have been rumors of Microsoft's offering around \$20 million for Xobni, but the young cofounders didn't bite. Instead, they intend to offer a "Pro" version and à la carte features for sale. Xobni also plans to extend its reach to other e-mail programs, including Web-based services such as Yahoo Mail and Gmail. And the team has already begun building in access to social networks such as LinkedIn.



FRESH OUTLOOK Adam Smith created Xobni, a plug-in for Microsoft Outlook that offers easy access to useful information about e-mail correspondents.

Other companies have tried to streamline e-mail before. But if Xobni can reach a significant fraction of the world's 400 million Outlook users, Smith may save people time and annoyance by making e-mail more useful. -Om Malik

HOSSAM HAICK, 33

Technion-Israel Institute of Technology Sniffing out cancer

HOSSAM Haick, a senior lecturer in chemical engineering, has created an electronic "nose" that can diagnose cancer in just two or three minutes by analyzing a patient's breath.

When a cancerous tumor develops in the body, its cells produce various chemicals that appear in the urine and blood. These biomarkers cross from the blood into the lungs, where they are exhaled in minuscule amounts. Haick's device detects cancer by "sniffing out" those telltale molecules; the current version can even distinguish between lung, breast, and colon cancer. He has begun testing the nose in collaboration with the oncology division of the Rambam Medical Center in Haifa. The finished device should be portable and inexpensive, providing a faster, easier, and more sensitive way to screen for tumors. Such screening should help doctors detect cancer early, when it's most treatable. Haick hopes the nose will eventually be as small as a cell phone and sophisticated enough to pinpoint a tumor's location. -Kristina Grifantini

BIOTECHNOLOGY

Joo Chuan Tong, 31

The Singapore Agency for Science, Technology, and Research's Institute for Infocomm Research My vision: Personalized vaccines

In recent years, Asia has been the epicenter of many emerging and reëmerging diseases, including avian influenza, severe acute respiratory syndrome (SARS), malaria, and chikungunya. The 2003 SARS epidemic, which coincided with the start of my PhD at the National University of Singapore's department of biochemistry, left a particular impression on me. Thus began my quest for more effective ways to create vaccines to combat such diseases.

Vaccination is a powerful tool. Each person's immune system is unique, however, and vaccines do not take these individual differences into account. So although today's vaccines protect the majority, some people fail to develop immunity, while others may have adverse reactions. At the same time, rapidly mutating bacteria and viruses evolve to evade immune protection. Every time a new strain emerges, a new vaccine must be created, as with the annual flu shot.

If we could map out the genetic profile of each individual's immune system, efficiently create vaccines against



the newest strains of a disease, and match the two, we would stand a far better chance of protecting people. At the Institute for Infocomm Research, I lead a team that is developing computer algorithms to help make this dream of personalized vaccines possible.

Our bodies rely on proteins called human leukocyte antigens (HLAs) to recognize foreign substances (i.e., antigens) from disease-causing microbes and marshal our immune systems against them. These same proteins process the antigens in vaccines, triggering resistance. But there are thousands of variants of the 11 HLA proteins, and each person inherits at most two of the possible variants for each one. Our algorithms take those genetic differences into

account to help select antigens that are most effective in triggering an immune response.

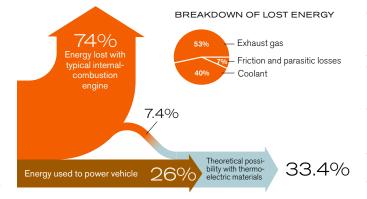
We begin by creating 3-D models of the interactions between different HLA molecules and antigens. We then use those models to train machine-learning algorithms to identify antigens likely to bind to the largest variety of HLA molecules; those antigens have the best potential to be effective vaccines. Our goal is to create models of the 120 to 150 most common HLA variants, which should cover 95 percent of the global population. By matching possible antigens with the HLA variants most common in a population, vaccines may be tailored to specific groups or, with personal screening, even to individuals. -Joo Chuan Tong

ENERGY RONGGUI YANG, 34

University of Colorado, Boulder Efficient electricity from waste heat

THERMOELECTRIC materials, which generate electricity from heat otherwise lost through vehicle exhaust pipes, industrial equipment, and computer chips, could do a lot to help conserve energy and reduce greenhouse-gas emissions. So far, however, they have been too inefficient and expensive to be widely used. Some newer thermoelectric materials might more effectively convert waste heat into useful electricity, but they require expensive and impractical layer-bylayer assembly.

Mechanical engineer Ronggui Yang has created an easy-to-make



HOT STUFF In today's cars, the bulk of fuel energy is lost, mostly as heat. Applied to strategic parts of a car's exhaust or cooling system, Yang's materials could transform 10 percent of a car's total lost heat into electricity. This electricity could be used to propel the car or to power accessories, theoretically increasing fuel economy by roughly 30 percent.

alternative: nanocomposites made of semiconductors such as silicongermanium alloys and bismuth telluride alloys. Because thermoelectrics generate a current when

exposed to a heat differential, they must have the unusual property of conducting electricity well but heat poorly. Yang is improving the thermoelectric performance of

the materials he uses by turning them into nanoparticles and nanowires, which he then fuses to create composite materials. The nanoscale components help inhibit the flow of heat, which is conveyed by atomic vibrations. That increases the thermoelectric efficiency of the finished material. Yang's theoretical work shows that the materials can match or improve on the efficiency of today's best thermoelectrics.

The biggest advantage of Yang's nanocomposites is that they could be mass-produced using a common industrial process. Yang has produced prototypes in conjunction with MIT, Boston College, and NASA's Jet Propulsion Laboratory at Caltech. Eventually, low-cost nanocomposites could offer big payoffs—for instance, significantly boosting the fuel efficiency of cars. -David Talbot

BIOTECHNOLOGY

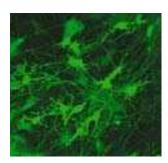
CHRISTOPHER CHANG, 33

University of California, Berkeley Probing chemical reactions in the body

CHRISTOPHER Chang wants to revolutionize cellular imaging by changing the way biologists tag the molecules they want to see. Most tags fluoresce continuously, and each one binds to a target molecule of a specific shape. Chang, however, is developing probes that fluoresce only when they react chemically with their targets. This will allow scientists to observe the genera-

tion, accumulation, and release of molecules involved in passing signals within and between cells.

For example, one of Chang's tags glows green when it reacts with hydrogen peroxide—a chemical found throughout the brain, where its function is largely unknown. The brighter the color, the more hydrogen peroxide a cell is taking up. Chang has used this tag to study



neurons from the hippocampus, a brain area vital for learning and memory (above). His research shows that the chemical, known mostly for causing cell damage, also plays an important role in neural signaling. —Emily Singer

SOFTWARE

Andrew Ng, 32 Stanford University

Building household robots

HOUSEKEEPING robots are still the stuff of science fiction, but not for want of hardware: there's almost no task too precise or delicate for a robot that knows in advance what it's supposed to do. The problem lies in teaching robots to deal with the unknown. That's precisely what Andrew Ng, an assistant professor of computer science, set out to do when he founded the Stanford Artificial Intelligence Robot (STAIR) project a few years ago.

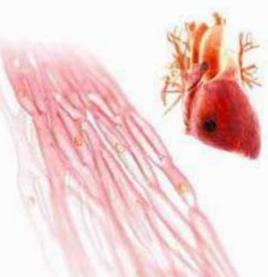
Previous robots have had some ability to improvisemany could locate familiar objects in unfamiliar environments, for example. But Ng has gone a step further: STAIR can deduce how to pick up an object it's never seen before. Using traditional machine-learning techniques, Ng trained STAIR on a database of pictures of objects such as wine glasses, coffee mugs, and pencils, as seen from different perspectives. Each object was correlated with information about the best place to grasp it: the stem of the wine glass, the middle of the pencil. After its training, STAIR could generalize those associations to adapt to new situations-lifting, among other things, a lunch

BIOTECHNOLOGY

Milica Radisic, 32

University of Toronto
Patching damaged hearts

The heart has a limited capacity to generate new cells on its own, making it hard to heal after injury. Scientists have experimented with injecting stem cells into the heart, but they have found it difficult to predict how the cells will behave, and they've had little success in coaxing cells to make functional tissue. To better anticipate which cell types may help heal hearts, bioengineer Milica Radisic has used embryonic stem cells to create a small patch that mimics human heart tissue.



Radisic grew her first heart patches using cells from the hearts of newborn rats. But coaxing the cells to form functioning heart tissue proved challenging; established tissue-engineering techniques didn't work. Radisic hit upon the idea of applying a small electric field to the cardiac cells, similar to the one formed as the heart develops in an embryo. This spurred the cells to connect in patterns that resembled those of actual heart tissue.

Radisic, an assistant professor of chemical engineering, is now using the same technique to grow heart patches derived from human embryonic stem cells. The patches respond to various stimuli as real heart muscle would, providing a way to more accurately test the potential of different cell

HEALING HEARTS
Milica Radisic creates
patches of beating
heart tissue (left) to
help figure out how
to use stem cells to
repair injured hearts.

lines and new drugs.
Radisic is now adding various lines of stem cells to the engineered patches to see which—if any—multiply and form functioning heart tis-

sue; her goal is to find cells that are useful in repairing muscle damaged by a heart attack or by high blood pressure. She also aims to help researchers find treatments for heart damage associated with diabetes by designing a patch that simulates the heart tissue of a person with that disease. —Jennifer Chu



box by its handle and a piece of intricate lab equipment by its metal stem. It was even able to remove dishes from a dishwasher and place them on a drying rack.

The STAIR team has made other advances-its innovative system for robotic depth perception even spawned a side project, software that converts static 2-D photographs into 3-D images.

But despite this progress, Ng knows that building a general-purpose household robot is beyond the means of any one lab. So he's developing an open-source robotics operating system that will let researchers integrate a robot's sensor systems and functional components in new ways, without having to write code from scratch. -Larry Hardesty

ROBO-MAID It takes a lot of imaging hardware to give the Stanford AI Robot its remarkable versatility. On the top rack are a 3-D laser scanner and a camera that takes three offset images. Below them are a "depth camera" that produces images of the distance to objects, a wide-angle camera, and a camera that can pan, tilt, and zoom in on objects the robot is trying to identify. Just above the inverted word "sick" is a horizontal laser scanner.



TELECOM SUNDAR **IYER. 31** Cisco Systems Making memory at Internet speed

PROBLEM: At the heart of the Internet are the routers that direct packets of data to their destinations. But by briefly holding each packet in memory while figuring out where to send it, these specialized computers create a bottleneck. The speed of today's 10-gigabitper-second links forces router makers to use fast but expensive static random-access memory (SRAM) instead of slower, cheaper digital random-access memory (DRAM). As connection speeds increase, the amount of SRAM needed will become prohibitively expensive, leading to data loss and limiting applications such as voice calls and videoconferencing.

SOLUTION: As a graduate student at Stanford, Sundar lyer created a technique that lets equipment makers combine SRAM with DRAM to make routers at once faster, more reliable, less expensive, and more energy efficient. In lyer's "perfect caching" scheme, each arriving data packet is stored in an SRAM chip. Once every hundred nanoseconds, the cache sends all the packets to the main memory, made from DRAM. Fifty nanoseconds later, another SRAM cache takes only the packets it needs and sends them to their destinations. Iyer founded Nemo Systems to develop the technology in 2003; Cisco bought Nemo in 2005 and is building the system into its next generation of enterprise routers. -Neil Savage

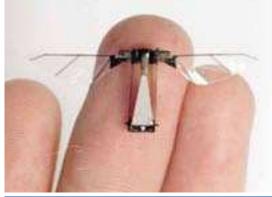
HARDWARE

ROBERT WOOD, 31

Harvard University Building robotic flies

ROBOTIC flies equipped with cameras, microphones, and other sensors would be a spy's dream. But researchers have had trouble creating the materials needed to make robots that look and behave like real insects. Robert Wood, an assistant professor of engineering and applied sciences, took on the challenge: he developed a revolutionary fabrication technique that allows engineers to make a range of very tiny parts for any kind of robot.

Wood's technique bears similarities to origami. To create three-dimensional structures that bend and rotate precisely as needed-not only for flying robots, but also for crawlers and swimmers-Wood builds "fold lines" into layered composites of





FLYING MACHINES Wood's robotic fly (top) is about the size of a small horsefly. A tiny actuator in its center bends and vibrates in response to an electric field, sending power to the wings. Wood recently added a robotic dragonfly to his menagerie (bottom); by studying the more complex aerodynamics of a four-winged system, he hopes to better understand maneuvering, propulsion, and other aspects of flight.

materials such as polymers or carbon fiber. Last year he used the method to build the world's smallest robotic insect capable of taking off. It is powered and controlled externally,

but he plans to develop an onboard power source and sensors, and to refine the robot's control systems. Wood's ultimate goal is a fully autonomous robotic insect. - Kristina Grifantini

SOFTWARE

Tanzeem Choudhury, 33

Dartmouth College Inferring social networks automatically

SOCIAL-NETWORKING sites such as Facebook require users to find and confirm connections with other people. But what if your cell phone could automatically identify the people you know, and even sort them into categories?

If that capability arrives, it will be thanks to reality mining, a field that Tanzeem Choudhury pioneered as a PhD student at the MIT Media Lab. Working at Intel after graduation, she created a pager-size sensor pack—loaded with software plus microphones, accelerometers, and other data-gathering devices-to collect and analyze data about human interactions and activity. For instance, by processing verbal utterances, she can identify the most influential people in a social network.

Now an assistant professor of computer science at Dartmouth, Choudhury is conducting experiments with the sensorladen iPhone. Within a few years, she says, simple versions of her software could be available for cell phones. -Kate Greene

ENERGY

Ric Fulop, 33

Energizing rechargeable batteries

In 2001, a professor of materials science **▲** and engineering at MIT, Yet-Ming Chiang, announced some promising results concerning new battery materials. But those materials might still be in the lab today were it not for Ric Fulop, then an enterprising 26-year-old from Venezuela. Today, the materials are being used to make high-performance batteries that General Motors is testing for use in its new electric car, the Volt.

Fulop founded his first company—which imported computer hardware and software and sold it to Venezuelan retailers-at

the age of 16. He has since founded five more companies, including one, Into Networks, whose software is used in the Windows Vista operating system. But it is at A123 Systems, the company he founded with Chiang in 2001, that Fulop has had his greatest success.

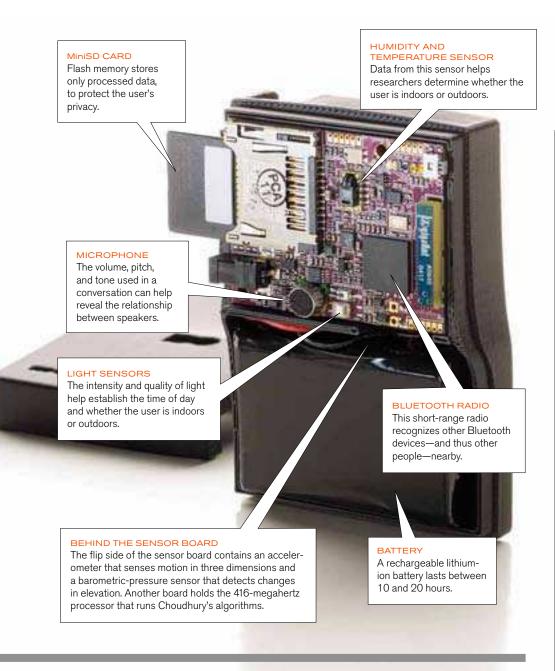
Now the company's vice president of business development, he has helped A123 raise over \$250 million, including investments from Sequoia Capital, GE, and OnPoint, the venture capital initiative of the U.S. Army. A123's batteries can already be found

in power tools, airplanes, and hybrid buses.

Fulop dropped out of college to found one of his companies, only to return for an MBA after starting A123. But despite a lack of academic training in materials science, he is quick to grasp technical







details. He spent months scouring scientific journals, attending conferences, and picking the brains of university technology licensing officers before his search led him to Yet-Ming Chiang. And thanks to this preparation, it took just one meeting to convince the MIT professor that Fulop's idea for a battery company was sound.

Commercializing battery technology, especially for new cars, is a capital-intensive and risky business. To help jump-start the company, Fulop helped negotiate a deal with Black and Decker to supply batteries for the power-tool market. Not only did the agreement give A123 an early and muchneeded source of revenue from an industrial customer, but it was an ideal way to start testing its production technology for the much larger automotive market. In 2006, partly on the strength of the company's success in reliably producing millions of battery cells a year for power tools, Fulop and his partners persuaded GM to give A123 a chance. The automaker is testing two different battery technologies for its Volt, with a decision expected by the end of the year. If GM does select A123's technology, Fulop will have played a key role in making possible the United States' first mass-produced electric car. -Kevin Bullis



SOFTWARE SETH HALLEM, 28 Coverity Deconstructing software to find bugs

PROBLEM: Programmers, despite their best efforts, make errors, any one of which could cause a system to crash or admit an attacker. Although automated test programs have improved software, major bugs still slip through, costing businesses and governments billions of dollars each year.

SOLUTION: As a graduate student at Stanford, Seth Hallem perfected an improved approach to finding bugs, called static analysis. Where ordinary test software runs a program and hopes to stumble on errors, static analysis breaks it into pieces that perform discrete functions, such as "add the results of lines 42 to 47." The computer determines what each piece does and then simulates how various functions might interact, looking for problematic combinations.

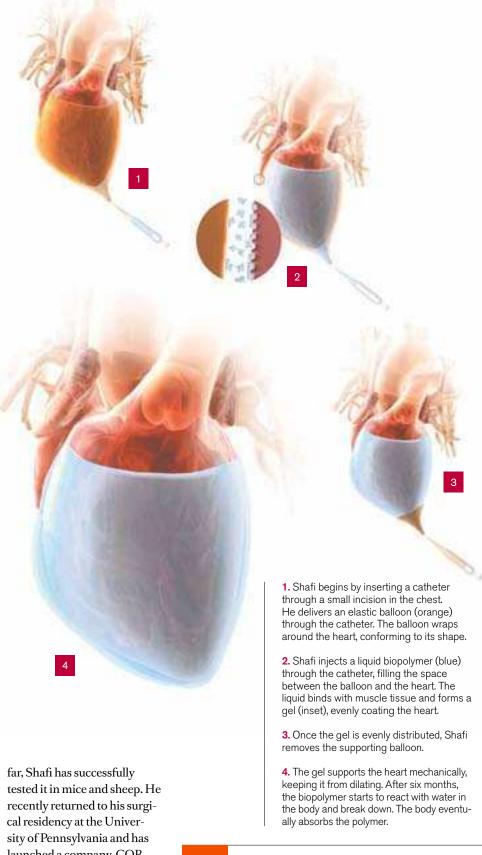
Previous attempts at static analysis were either too simplistic to find important bugs or too comprehensive to ever finish the job. Hallem developed algorithms to weed out redundant analysis and examine only the most important combinations, allowing millions of lines of code to be examined quickly and effectively. He cofounded Coverity in San Francisco to apply the technology commercially. More than 450 customers, including Raytheon and Yahoo, use Coverity's tools to vet their software. -Neil Savage

Bilal Shafi, 34

University of Pennsylvania Preventing congestive heart failure

Three years ago, surgical resident Bilal Shafi was in the thick of a heart transplant. The patient was a heart attack survivor whose heart function had silently continued to deteriorate, as it does in 30 percent of such cases. When that happens, the heart works harder, expanding to keep up its pumping ability and stretching its walls thin. Shafi had previously helped to install a permanent textile mesh around the patient's heart, an experimental and extreme procedure meant to prevent further dilation and ultimate heart failure. But the patient grew sick enough to require a transplant. During the surgery, Shafi thought, "Why aren't we treating this disease much earlier?"

So he became a fellow in the Stanford Biodesign Innovation program and, over the next three years, developed a biopolymer coating that wraps around the heart and prevents dilation. The coating, which starts out as a liquid, is injected through a catheter immediately following a heart attack. Then it gels, becoming flexible enough to expand with each heartbeat, yet firm enough to support the heart and allow it to heal. After six months, the polymer degrades and the body absorbs it. So



launched a company, COR Innovations, to further develop the technology. -Jennifer Chu

www

Find more information about the 2008 TR35, including videos and slide shows: technologyreview.com/tr35



SOFTWARE Blaise Agüeray Arcas, 33

Microsoft Live Labs **Building immersive** 3-D environments



IMAGINE taking hundreds of photos in the Rockies and being able to piece the images into a virtual re-creation of the peaks. With Microsoft's Photosynth, you can.

Created by Blaise Agüera y Arcas, the software uses digital photos to construct 3-D environments called "synths." Agüera y Arcas created the first version in 2006, drawing on Seadragon-a data navigation technology he'd developed previously-and computer vision research from Microsoft and the University of Washington.

In August, Agüera y Arcas and his team released a version of Photosynth that allows users to construct their own synths for the first time. The software runs on users' computers and includes algorithms that let them more easily pivot in 3-D space. It also allows them to post their synths online and discover other synths of the same or similar places. As users add synths of cities, stores, and homes, Agüera y Arcas says, the Photosynth site will be able to "enrich online 3-D mapping, shopping, real estate, and other immersive Web applications that involve real objects and places." -Brittany Sauser

"SYNTH": THE PARTHENON

Microsoft has partnered with the National Geographic Society to combine highquality photos of historic sites, such as the Parthenon, into "synths" that allow users to virtually explore the spaces. Photosynth's machine vision algorithms figure out which features the images have in common and create a "point cloud"—a bloom of dots that form a 3-D model of the image.

Using the point cloud, additional algorithms identify the angles and distances from which the various images were captured and then connect the dots to stitch the photos into a full 3-D simulation of the site. The viewing software allows users to fluidly navigate the synth.



BIOTECHNOLOGY **MARTIN** BURKE, 32 University of Illinois Molecular diversity

PROBLEM: Of the thousands of drugs used to treat disease, most are small molecules—organic compounds that bind with proteins and influence their activity. But researchers must screen many compounds to find potential drugs, and the large number of chemical reactions needed to synthesize any one compound makes the process slow and painstaking.

SOLUTION: Martin Burke, an assistant professor of chemistry, has figured out a way to simply and quickly generate diverse arrays of small molecules by repeatedly using a single reaction to join different organic components. He begins by turning a wide variety of organic molecules into standardized building blocks, each of which has a boronic acid on one end and a halide, such as bromide, on the other. In a test tube, the two ends react to link molecules with a carbon-carbon bond. Burke's key advance is a way to reversibly obstruct the boronic-acid end, so that chemists can sequentially couple different molecules.

Burke is partnering with a major chemical company to release a set of premade building blocks. Ultimately, he hopes that the ability to quickly create large collections of compounds will help him find highly complex small molecules that can imitate the structure of proteins that malfunction in diseases such as cystic fibrosis. Such "molecular prosthetics" could provide new treatments for a whole array of diseases, saving lives. -Lissa Harris

How Obama Really Did It

SOCIAL TECHNOLOGY HELPED BRING HIM TO THE BRINK OF THE PRESIDENCY

By DAVID TALBOT

oe Trippi, Howard Dean's 2004 presidential campaign manager and Internet impresario, describes Super Tuesday II—the March 4 primaries in Texas, Ohio, Vermont, and Rhode Island—as the moment Barack Obama used social technology to decisive effect. The day's largest hoard of delegates would be contested in Texas, where a strong showing would require exceptional discipline and voter-education efforts. In Texas, Democrats vote first at the polls and then, if they choose, again at caucuses after the polls close. The caucuses award one-third of the Democratic delegates.

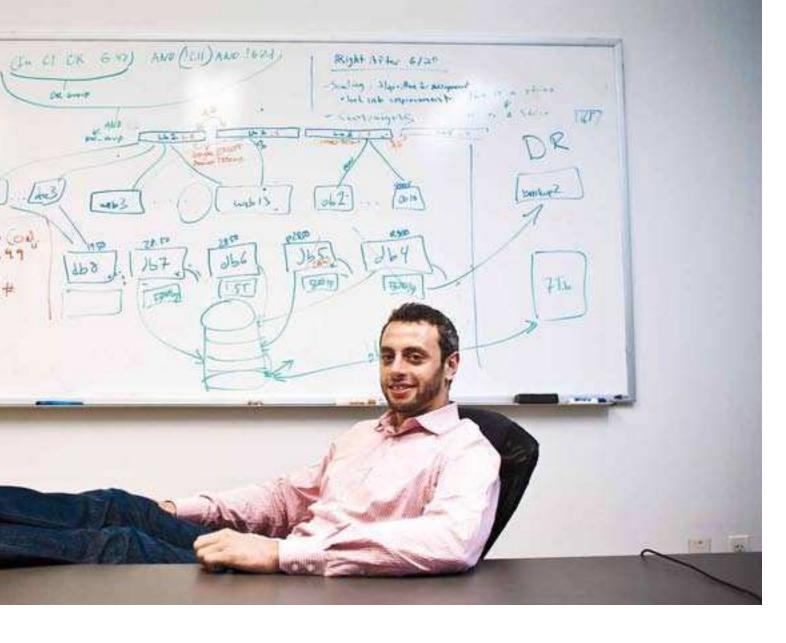
Hillary Clinton's camp had about 20,000 volunteers at work in Texas. But in an e-mail, Trippi learned that 104,000 Texans had joined Obama's social-networking site, www.my.barackobama.com, known as MyBO. MyBO and the main Obama site had already logged their share of achievements, particularly in helping rake in cash. The month before, the freshman senator from Illinois had set a record in American politics by garnering \$55 million in donations in a single month. In Texas, MyBO also gave the Obama team the instant capacity to wage fully networked campaign warfare. After seeing the volunteer numbers, Trippi says, "I remember saying, 'Game, match—it's over."

The Obama campaign could get marching orders to the Texans registered with MyBO with minimal effort. The MyBO databases could slice and dice lists of volunteers by geographic microregion and pair people with appropriate tasks, including prepping nearby voters on caucus procedure. "You could go online and download the names, addresses, and phone numbers of 100 people in your neighborhood to get out and vote—or the 40 people on your block who were undecided," Trippi says. "'Here is the leaflet: print it out and



get it to them.' It was you, at your computer, in your house, printing and downloading. They did it all very well." Clinton won the Texas primary vote 51 to 47 percent. But Obama's people, following their MyBO playbook, so overwhelmed the chaotic, crowded caucuses that he scored an overall victory in the Texas delegate count, 99 to 94. His showing nearly canceled out Clinton's win that day in Ohio. Clinton lost her last major opportunity to stop the Obama juggernaut. "In 1992, Carville said, 'It's the economy, stupid,'" Trippi says, recalling the exhortation of Bill Clinton's campaign manager, James Carville. "This year, it was the network, stupid!"

Throughout the political season, the Obama campaign has dominated new media, capitalizing on a confluence of trends. Americans are more able to access media-rich content online; 55 percent have broadband Internet connections at home, double the figure for spring 2004. Social-networking technologies have matured, and more Americans are comfortable with them. Although the 2004 Dean campaign broke ground with its online meeting technologies and blogging, "people didn't quite have the facility," says Lawrence



Lessig, a Stanford law professor who has given the Obama campaign Internet policy advice (Lessig wrote "The People Own Ideas!" in our May/June 2005 issue, available on technologyreview.com). "The world has now caught up with the technology." The Obama campaign, he adds, recognized this early: "The key networking advance in the Obama field operation was really deploying community-building tools in a smart way from the very beginning."

Of course, many of the 2008 candidates had websites, click-to-donate tools, and social-networking features—even John McCain, who does not personally use e-mail. But the Obama team put such technologies at the center of its campaign—among other things, recruiting 24-year-old Chris Hughes, cofounder of Facebook, to help develop them. And it managed those tools well. Supporters had considerable discretion to use MyBO to organize on their own; the campaign did not micromanage but struck a balance between top-down control and anarchy. In short, Obama, the former Chicago community organizer, created the ultimate online political machine.

WEB JOCKEY Jascha Franklin-Hodge, the 29-year-old cofounder and chief technology officer of Blue State Digital, the company behind Obama's social technologies, says that "on every metric, this campaign has operated on a scale that has exceeded what was done before." Beyond fund-raising, the Web tools enabled event planning, phone banks, and targeted e-mailing.

The Obama campaign did not provide access or interviews for this story; it only confirmed some details of our reporting and offered written comments. This story is based on interviews with third parties involved in developing Obama's social-networking strategy or who were familiar with it, and on public records.

AN ONLINE NERVOUS SYSTEM

A row of elegant, renovated 19th-century industrial buildings lines Boston's Congress Street east of Fort Point Channel. On any given day, behind a plain wooden door on the third floor of 374 Congress, 15 to 20 casually clad programmers tap away at computers. On the day I visited, the strains of Creedence Clearwater Revival filled the room; a Ping-Pong table dominated the small kitchen. This is the

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technology center for Blue State Digital, which means that it is also the nervous system for its two largest clients, the Barack Obama campaign and the Democratic National Committee. Founded by alumni of the Dean campaign, Blue State Digital added interactive elements to Obama's website—including MyBO—and now tends to its daily care and feeding. The site's servers hum away in a Boston suburb and are backed up in the Chicago area.

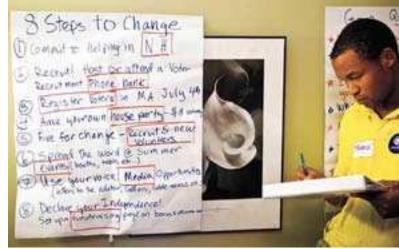
Jascha Franklin-Hodge, 29, greeted me with a friendly handshake and a gap-toothed grin. He has a deep voice and a hearty laugh; his face is ringed by a narrow beard. Franklin-Hodge

dropped out of MIT after his freshman year and spent a few years in online music startups before running the Internet infrastructure for the Dean campaign, which received a then-unprecedented \$27 million in online donations. "When the campaign ended, we thought, 'Howard Dean was not destined to be president, but what we are doing online—this is too big to let go away," he says. He and three others cofounded Blue State Digital, where he is chief technology officer. (Another cofounder, Joe Rospars, is now on leave with the Obama campaign as its new-media director.)

The MyBO tools are, in essence, rebuilt and consolidated versions of those created for the Dean campaign. Dean's website allowed supporters to donate money, organize meetings, and distribute media, says Zephyr Teachout, who was Dean's Internet director and is now a visiting law professor at Duke University. "We developed all the tools the Obama campaign is using: SMS [text messaging], phone tools, Web capacity," Teachout recalls. "They [Blue State Digital] did a lot of nice work in taking this crude set of unrelated applications and making a complete suite."

Blue State Digital had nine days to add its tools to Obama's site before the senator announced his candidacy on February 10, 2007, in Springfield, IL. Among other preparations, the team braced for heavy traffic. "We made some projections of traffic levels, contribution amounts, and e-mail levels based on estimates from folks who worked with [John] Kerry and Dean in 2004," recalls Franklin-Hodge. As Obama's Springfield speech progressed, "we were watching the traffic go up and up, surpassing all our previous records." (He would not provide specific numbers.) It was clear that early assumptions were low. "We blew through all of those [estimates] in February," he says. "So we had to do a lot of work to make sure we kept up with the demand his online success had placed on the system." By July 2008, the campaign had raised more than \$200 million from more than a million online donors (Obama had raised \$340 million from all sources by the end of June), and MyBO had logged more than a million user accounts and facilitated 75,000 local events, according to Blue State Digital.





MyBO and the main campaign site made it easy to give money—the fuel for any campaign, because it pays for advertising and staff. Visitors could use credit cards to make one-time donations or to sign up for recurring monthly contributions. MyBO also made giving money a social event: supporters could set personal targets, run their own fund-raising efforts, and watch personal fund-raising thermometers rise. To bring people to the site in the first place, the campaign sought to make Obama a ubiquitous presence on as many new-media platforms as possible.

The viral Internet offered myriad ways to propagate unfiltered Obama messages. The campaign posted the candidate's speeches and linked to multimedia material generated by supporters. A music video set to an Obama speech—"Yes We Can," by the hiphop artist Will.i.am—has been posted repeatedly on YouTube, but the top two postings alone have been viewed 10 million times. A single YouTube posting of Obama's March 18 speech on race has been viewed more than four million times. Similarly, the campaign regularly sent out text messages (at Obama rallies, speakers frequently asked attendees to text their contact information to his campaign) and made sure that Obama was prominent on other



YES, WE NETWORK After Hillary Clinton suspended her campaign, Barack Obama's campaign e-mailed members of its social-networking site exhorting them to hold "Unite for Change" parties on June 28. More than 4,000 parties—arranged by supporters using the Obama site—were organized in days; these are scenes from three such parties in the Boston area. The Obama site has helped volunteers organize more than 75,000 events.

social-networking sites, such as Facebook and MySpace (see "New-Media King," p. 82). The campaign even used the microblogging service Twitter, garnering about 50,000 Obama "followers" who track his short posts. "The campaign, consciously or unconsciously, became much more of a media operation than simply a presidential campaign, because they recognized that by putting their message out onto these various platforms, their supporters would spread it for them," says Andrew Rasiej, founder of the Personal Democracy Forum, a website covering the intersection of politics and technology (and another Dean alumnus). "We are going from the era of the sound bite to the sound blast."

Money flowed in, augmenting the haul from big-ticket fundraisers. By the time of the Iowa caucuses on January 3, 2008, the Obama campaign had more than \$35 million on hand and was able to use MyBO to organize and instruct caucus-goers. "They have done a great job in being precise in the use of the tools," Teachout says. "In Iowa it was house parties, looking for a highly committed local network. In South Carolina, it was a massive get-out-the-vote effort." MyBO was critical both in the early caucus states, where campaign staff was in place, and in later-voting states like Texas, Colorado, and Wisconsin, where "we provided the tools, remote training, and opportunity for supporters to build the campaign on their own," the Obama campaign told *Technology Review* in a written statement. "When the campaign eventually did deploy staff to these states, they supplemented an already-built infrastructure and volunteer network."

Using the Web, the Obama camp turbocharged age-old campaign tools. Take phone banks: through MyBO, the campaign chopped up the task of making calls into thousands of chunks small enough for a supporter to handle in an hour or two. "Millions of phone calls



were made to early primary states by people who used the website to reach out and connect with them," Franklin-Hodge says. "On every metric, this campaign has operated on a scale that has exceeded what has been done before. We facilitate actions of every sort: sending e-mails out to millions and millions of people, organizing tens of thousands of events." The key, he says, is tightly integrating online activity with tasks people can perform in the real world. "Yes, there are blogs and Listservs," Franklin-Hodge says. "But the point of the campaign is to get someone to donate money, make calls, write letters, organize a house party. The core of the software is having those links to taking action—to doing something."

PORK INVADERS

If the other major candidates had many of the same Web tools, their experiences show that having them isn't enough: you must make them central to the campaign and properly manage the networks of supporters they help organize. Observers say that Clinton's campaign deployed good tools but that online social networks and new media weren't as big a part of its strategy; at least in its early months, it relied more on conventional tactics like big fundraisers. After all, Clinton was at the top of the party establishment. "They [the Obama supporters] are chanting 'Yes we can,' and she's saying 'I don't need you," Trippi says. "That is what the top of that campaign said by celebrating Terry McAuliffe [the veteran political operative and former Democratic National Committee chairman] and how many millions he could put together with big, big checks. She doesn't need my \$25!" The two campaigns' fund-raising statistics support Trippi's argument: 48 percent of Obama's funds came from donations of less than \$200, compared with 33 percent of Clinton's, according to the Center for Responsive Politics.

Clinton's Internet director, Peter Daou, credits the Obama campaign with doing an "amazing job" with its online social network. "If there is a difference in how the two campaigns approached [a Web strategy], a lot of those differences were based on our constituencies," Daou says. "We were reaching a different demographic of supporters and used our tools accordingly." For example, he says, the Clinton campaign established a presence on the baby-boomer social-networking site Eons.com, and Clinton herself often urged listeners to visit www.hillaryclinton.com. But Andrew Rasiej says that the conventional political wisdom questioned the value of the Internet. "As far as major political circles were concerned," he says, "Howard Dean failed, and therefore the Internet didn't work."

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While it's hard to tease out how much Clinton's loss was due to her Web strategy-and how much to factors such as her Iraq War vote and the half-generation difference between her and Obama's ages-it seems clear that her campaign deëmphasized Web strategy early on, Trippi says. Even if you "have all the smartest bottom-up, tech-savvy people working for you," he says, "if the candidate and the top of the campaign want to run a top-down campaign, there is nothing you can do. It will sit there and nothing will happen. That's kind of what happened with the Clinton campaign."

Republican Ron Paul had a different problem: Internet anarchy. Where the Obama campaign built one central network and managed it effectively, the Paul campaign decided early on that it would essentially be a hub for whatever networks the organizers were setting up. The results were mixed. On the one hand, volunteers organized successful "money bombs"-one-day online fund-raising frenzies (the one on November 5, 2007, netted Paul \$4.3 million). But sometimes the volunteers' energy-and money-was wasted, says Justine Lam, the Paul campaign's Internet director, who is now the online marketing director at Politicker.com. Consider the supporter-driven effort to hire a blimp emblazoned with "Who is Ron Paul? Google Ron Paul" to cruise up and down the East Coast last winter. "We saw all this money funding a blimp, and thought, 'We really need this money for commercials," Lam says.

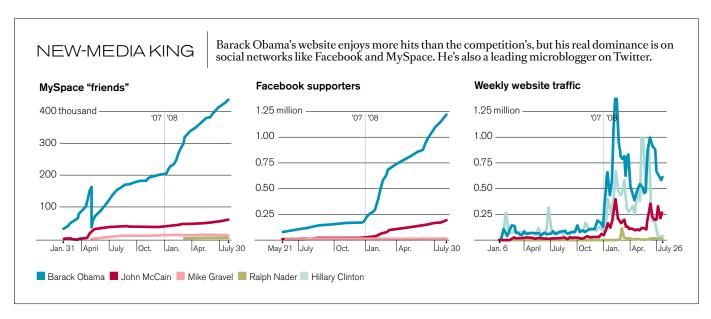
Then there is McCain, who-somewhat ironically-was the big Internet story of 2000. That year, after his New Hampshire primary victory over George W. Bush, he quickly raised \$1 million online. And at times last year, he made effective use of the Internet. His staff made videos-such as "Man in the Arena," celebrating his wartime service—that gained popularity on YouTube. But the McCain site is ineffectual for social networking. In late June,

when I tried to sign up on McCainSpace—the analogue to MyBO— I got error messages. When I tried again, I was informed that I would soon get a new password in my in-box. It never arrived. "His social-networking site was poorly done, and people found there was nothing to do on it," says Lam. "It was very insular, a walled garden. You don't want to keep people inside your walled garden; you want them to spread the message to new people."

McCain's organization is playing to an older base of supporters. But it seems not to have grasped the breadth of recent shifts in communications technology, says David All, a Republican newmedia consultant. "You have an entire generation of folks under age 25 no longer using e-mails, not even using Facebook; a majority are using text messaging," All says. "I get Obama's text messages, and every one is exactly what it should be. It is never pointless, it is always worth reading, and it has an action for you to take. You can have hundreds of recipients on a text message. You have hundreds of people trying to change the world in 160 characters or less. What's the SMS strategy for John McCain? None."

The generational differences between the Obama and McCain campaigns may be best symbolized by the distinctly retro "Pork Invaders," a game on the McCain site (it's also a Facebook application) styled after Space Invaders, the arcade game of the late 1970s. Pork Invaders allows you to fire bullets that say "veto" at slow-moving flying pigs and barrels.

But it's not that the campaign isn't trying to speak to the youth of today, as opposed to the youth of decades ago. Lately McCain has been having his daughter Meghan and two friends write a "bloggette" from the campaign trail. The bloggette site features a silhouette of a fetching woman in red high-heeled shoes. "It gives a hipper, younger perspective on the campaign and makes both of



In 1992, James Carville, Bill Clinton's campaign chief, famously exhorted his staff, "It's the economy, stupid!" This year, "It's the network, stupid!" says Joe Trippi, manager of Howard Dean's 2004 campaign, which midwifed Barack Obama's Web tools.

her parents seem hipper and younger," says Julie Germany, director of the nonpartisan Institute for Politics, Democracy, and the Internet at George Washington University. The McCain campaign did not reply to several interview requests, but Germany predicts that the campaign will exploit social networking in time to make a difference in November. "What we will see is that the McCain online campaign is using the Internet just as effectively to meet its goals as the Obama campaign," she says. Over the summer, the McCain campaign refreshed its website. But Rasiej, for one, doubts that McCain has enough time to make up lost ground.

A NETWORKED WHITE HOUSE?

The obvious next step for MyBO is to serve as a get-out-the-vote engine in November. All campaigns scrutinize public records showing who is registered to vote and whether they have voted in past elections. The Obama campaign will be able to merge this data with MyBO data. All MyBO members' activity will have been chronicled: every house party they attended, each online connection, the date and amount of each donation. Rasiej sees how it might play out: the reliable voters who signed up on MyBO but did little else may be left alone. The most active ones will be deployed to get the unreliable voters—whether MyBO members or not—to the polls. And personalized pitches can be dished up, thanks to the MyBO database. "The more contextual information they can provide the field operation, the better turnout they will have," he says.

If Obama is elected, his Web-oriented campaign strategy could carry over into his presidency. He could encourage his supporters to deluge members of Congress with calls and e-mails, or use the Web to organize collective research on policy questions. The campaign said in one of its prepared statements that "it's certain that the relationships that have been built between Barack Obama and his supporters, and between supporters themselves, will not end on Election Day." But whether or not a President Obama takes MyBO into the West Wing, it's clear that the phenomenon will forever transform campaigning. "We're scratching the surface," Trippi says. "We're all excited because he's got one million people signed up—but we are 300 million people in this country. We are still at the infancy stages of what social-networking technologies

www

Hear the CTO of Blue State Digital explain the origins and workings of Barack Obama's social-networking website: **technologyreview.com/obama**

are going to do, not just in our politics but in everything. There won't be any campaign in 2012 that doesn't try to build a social network around it."

Lessig warns that if Obama wins but doesn't govern according to principles of openness and change, as promised, supporters may not be so interested in serving as MyBO foot soldiers in 2012. "The thing they [the Obama camp] don't quite recognize is how much of their enormous support comes from the perception that this is someone different," Lessig says. "If they behave like everyone else, how much will that stanch the passion of his support?"

But for now, it's party time. At the end of June, after Clinton suspended her campaign, MyBO put out a call for the faithful to organize house parties under a "Unite for Change" theme. More than 4,000 parties were organized nationwide on June 28; I logged in and picked three parties from about a dozen in the Boston area.

My first stop was a house party in the tony suburb of Winchester, where several couples dutifully watched an Obama-supplied campaign video. Host Mary Hart, an art professor in her 50s, said that Obama and his website made her "open my house to strangers and really get something going." She added, "I'm e-mailing people I haven't seen in 20 years. We have this tremendous ability to use this technology to network with people. Why don't we use it?"

Next stop was a lawn party in the Boston neighborhood of Roxbury, whose organizer, Sachielle Samedi, 34, wore a button that said "Hot Chicks Dig Obama." She said that support for the Obama candidacy drew neighbors together. At the party, Wayne Dudley, a retired history professor, met a kindred spirit: Brian Murdoch, a 54-year-old Episcopal priest. The two men buttonholed me for several minutes; Dudley predicted that Obama would bring about "a new world order centered on people of integrity." Murdoch nodded vigorously. It was a fine MyBO moment.

My evening ended at a packed post-collegiate party in a Somerville walk-up apartment. Host Rebecca Herst, a 23-year-old program assistant with the Jewish Organizing Initiative, said that MyBO—unlike Facebook—allowed her to quickly upload her entire Gmail address book, grafting her network onto Obama's. "It will be interesting to see what develops after this party, because now I'm connected to all these people," she shouted over the growing din. Two beery young men, heading for the exits, handed her two checks for \$20. Herst tucked the checks into her back pocket.

DAVID TALBOT IS TECHNOLOGY REVIEW'S CHIEF CORRESPONDENT.

By MARK WILLIAMS

Obama's Geek

OF ECONOMIC ADVISOR FOR A NEW KIND OF PRESIDENTIAL CANDIDATE.

he Fourth of July is just days away, and on the Loop's crowded streets and plazas, outside the downtown campus of the University of Chicago Graduate School of Business, the city swelters. Upstairs, in an air-conditioned office, Austan Goolsbee is recounting how he was transformed from an economics professor into the senior economic advisor to a candidate for the presidency of the United States.

Goolsbee must pick his words more carefully now, but it's no great strain for him to tell a good story. The two men met in 2004, after Barack Obama became the Democratic contender for junior U.S. senator from Illinois and the Republicans fielded the perennial candidate Alan Keyes. Though Keyes's Christian Dominionist views on government and society have long made him unelectable, the Democrats wanted to ensure that Obama could demolish the opposition's economic platform. So his campaign contacted Goolsbee, whom Obama knew by reputation, from his own years teaching constitutional law at the University of Chicago, as an expert on much that was cutting-edge in economics.

Keyes's economic plan was to abolish the income tax and replace it with a national sales tax that exempted all housing, food, and transportation purchases as well as the spending of the poor and elderly. What would the sales tax have been for unexempted goods, I ask, if the U.S. government's operating revenues were to be maintained? About 70 percent, Goolsbee replies, laughing. During 2004, the Obama campaign grew accustomed to calling on Goolsbee's expertise. The candidate exchanged e-mails with the professor. Still, they had no face-to-face contact. The two finally met in October, during the second debate between Obama and Keyes, at the ABC studio in Chicago.

"I hung in this room outside with Michelle, who was cool," Goolsbee recalls. Finally, informed that the candidate was ready to receive him, he knocked on the door. "Obama opened the door, looked at me in bafflement, and said, 'Who are you?' I said, I'm Professor Goolsbee. Obama said, 'You can't be.'" He'd been expecting an older tweed-jacketed academic, not-as Goolsbee

claims Obama phrased it-another skinny, tall, youthful, geeky guy with big ears and a funny name.

Goolsbee, now 39, graduated from Yale in 1991, earned his doctorate from MIT in 1995, and in slightly more than a decade has built a remarkably broad résumé, which includes membership in the Panel of Economic Advisors to the U.S. Congressional Budget Office, columns in the New York Times and Slate, a Fulbright scholarship, and even a stint hosting a television show, History's Business, on the History Channel. As Tyler Cowen, an economics professor at George Mason University and the author of the popular blog Marginal Revolution, says: "Austan Goolsbee is smart."

Generations of the best and the brightest have come and gone in Washington, DC, usually without effecting significant changes. In this, Goolsbee may or may not turn out to be exceptional. Nevertheless, he is something different in a presidential campaign: he is part of a generation of economists who have focused on the Internet, network effects, behavioral economics, and neuroeconomics. Whether Obama wins or loses, this is the first time a U.S. presidential candidate has had a chief economic advisor whose outlook and skills are those of a 21st-century economist.

Moreover, if Obama does win, 2008 will be a watershed election in American political history for reasons unrelated to the new president's skin color. For decades, the resident of the White House has been closely associated with the South or Southwest. Now, someone from the intellectual milieu associated with the University of Chicago is a plausible candidate. Along with Goolsbee and other members of this intellectual movement-including Chicago Business School professor Richard Thaler, a founder of behavioral economics, and Cass Sunstein, a former professor at Chicago's law school-Obama subscribes to a distinctive set of economic theories developed at the university, and to a corresponding set of policy prescriptions. These people are Chicagoans, who-to paraphrase a native son-go at things in their own way, on the basis of first to knock, first admitted. If Obama reaches the White House, they will not be shy about implementing those prescriptions.



BEST BEHAVIOR

Twenty-first-century economics is preoccupied with technology, both as a force for change and as a source of insights about economic behavior. But Goolsbee admits he didn't initially grasp the transformative power of one new technology. "When I was at MIT, they had a beta test of Mosaic, the first popular browser," he says. "I remember looking at it, and there was a weather map or something. Now, in fairness to me, there weren't any websites then. But I remember saying, 'This is stupid—what's the point?' Now, of course, it's obvious. But at the time they all but handed me the World Wide Web and I was like, 'Aw, who cares?"

He soon caught on, however. "When the Internet first appeared, this heated debate developed among economists," he recalls. "One side said the Internet will make it easier for companies to pricediscriminate, and it'll be fabulously profitable. The other side argued that the Internet will be the great equalizer-it'll make markets close to perfectly competitive and people much more pricesensitive, and profits will be highly constrained. I'm probably the leading guy associated with that second position. Arguably, I got lucky, but what I wrote basically turned out to be correct."

Goolsbee's writings on this subject started bringing him "calls from all over the place, from policy makers and businesspeopleonline merchants, particularly." In the late 1990s, he published some highly influential papers that evaluated the depressive effects of taxation on Internet commerce. Finally, having been an assistant professor of economics at the University of Chicago Graduate School of Business since the age of 25, Goolsbee (who was born in Waco, TX, and grew up in California) gained tenure at 32.

Today's University of Chicago economists are quite unlike the free-market-fundamentalist followers of Milton Friedman who made the university famous in the last century. When Goolsbee and I return from lunch through the school's lobby, we pass displays of books and magazines promoting the faculty's research. Much of it resembles the stuff popularized by Steven Levitt's 2005 best-seller Freakonomics. Levitt, another University of Chicago economist who received his PhD from MIT, subtitled his book A Rogue Economist Explores the Hidden Side of Everything; in it, he applies contemporary economic analysis to subjects ignored by previous generations of economists-subjects like the poor earnings of inner-city crack dealers. Similarly, the school's publication Chicago GSB Magazine presents studies examining such questions as why many African-Americans, averaging a fraction of the financial worth of their white counterparts, invest more heavily in bling. In the context of the University of Chicago, Levitt, far from being a rogue economist, reflects a general rejection of some of the tenets of neoclassical economics.

According to neoclassical theory, individuals and groups act according to what economists call the rules of maximizing behavior-that is, individuals always act rationally to increase their own

personal advantage, and firms always act to maximize profits. Neoclassical economics has notorious logical difficulties. It presupposes that individuals possess the necessary information to make choices, without explaining how they acquire that information; and it assumes that people know their preferences sufficiently well to be good maximizers, yet it never accounts for how, when a new technology or other novelty appears, they discover those preferences in the first place. To address these shortcomings, economists like Levitt, Thaler, and Goolsbee have increasingly taken two general approaches that are broadly complementary.

First, they have turned to the empirical study of specific behaviors among restricted populations, because in such microeconomic contexts the data tend to be easily obtainable and to yield striking discoveries. Second, economists have imported insights from behavioral psychology and neuroscience.

There was one other best-selling book on display as we passed-Nudge: Improving Decisions about Health, Wealth, and Happiness, by Richard Thaler and Cass Sunstein. (Thaler is director of the Center for Decision Research at Chicago's business school. Though without a formal title in Obama's campaign, he consults regularly with Goolsbee. "My main role has been to harass Austan, who has an office down the hall from mine," he has said.) Nudge is an introduction to behavioral economics, which since the 1970s has accumulated a substantial body of lore. Often, it has developed such insights with the help of neuroeconomics, which uses technologies like magnetic resonance imaging (MRI) and positron emission tomography (PET) to capture the neural mechanics of decision making. At Nudge's beginning, Thaler and Sunstein provide readers with a big, easy metaphor: your brain, they write, is divided between your automatic system (your inner Homer Simpson) and your reflective system (your Mr. Spock).

What does all this have to do with Barack Obama? Much of Goolsbee's writing is more technical than Freakonomics and *Nudge*, and his own research focuses on taxation, the Internet, and network effects; but in his policy prescriptions he's very much of the new Chicago school of economics. When our tendencies to make irrational decisions are understood, the Chicago economists argue, we can design "choice architectures" (Thaler and Sunstein's phrase) so that people default to better choices about matters like investment or taxation. Hence Obama's proposal that companies offering 401(k) retirement accounts should enroll their workers automatically, making participation the default option and opting out a conscious choice. Thus, too, Goolsbee's plan to simplify income tax filing for that majority of Americans who take only the standard deduction: under Goolsbee's scheme, the IRS would send all those taxpayers a return with the relevant information, so that signing the prepared form would become the default choice-saving taxpayers 225 million hours and \$2 billion in preparation fees.

AMERICA AS HOSPITAL

In March it seemed as if Obama might throw Goolsbee under the bus. A furor erupted over a leaked memo, written by a Canadian official, telling his superiors that in a February 8 meeting at Canada's Chicago consulate, Goolsbee had given reassurances that the harsh rhetoric his candidate had voiced about the North American Free Trade Agreement while campaigning in Ohio—where many blame NAFTA for job losses—was only that. In the memo's words, Goolsbee explained that Obama's protectionist stance on the campaign trail was "more reflective of political maneuvering than policy." Unfortunately, one of the Obama campaign's first mass mailings had shown a padlocked factory gate with the words 'Only Barack Obama consistently opposed NAFTA." Although Goolsbee retained his title of senior economic advisor, he adopted (or was required to adopt) a lower profile.

With Hillary Clinton's quest for the nomination defeated, Goolsbee is, once again, prominent in Obama's run for the presidency. Still, the question remains: many American voters wish the U.S. industrial economy of the 1950s and '60s could be restored, and with it the sweet deal unskilled workers enjoyed. Politicians fail to pander at their peril, and globalization is often held at fault for economic insecurity. But is it?

"Economic research hasn't pointed at globalization as the main culprit," Goolsbee says. For example, he explains, Chinese and American manufacturing barely overlap: the total of all imports into the U.S. amounts to only 16.7 percent of American GDP, and imports from China amount to just 2.2 percent. "In fact, the losers to China have been nations like Mexico," he says; likewise, if Americans stopped buying cheap toys from China, the manufacturing jobs would return to nations like Mexico, not the U.S. Goolsbee adds, "Trade has helped the economy grow. Simultaneously, a sizable number of Americans haven't shared in that bounty, and if we don't pay attention to their concerns, all the political favor for open markets will dry up."

Rather than globalization, Goolsbee believes, "the change in the demand for skills and use of technology" has reduced average Americans' economic security. Then is the problem an unwillingness to change and acquire new skills—a kind of laziness? "Since as far as hours worked, people here are working more than in any other major economy, that's really not the issue," he says. "Americans are no lazier than any other people. It's been the long-standing trend that the U.S. economy has been much more focused on areas involving high human capital." At the same time it's mistaken, he insists, to fear some automated dystopia "where everybody below the 50th percentile loses their jobs," because in a growing economy, a range of skills will always be needed. "When productivity increases in any given segment of an economy, wages rise there, and this spills over into relatively unskilled workers' pay. Picture a hospital, where there are high-skilled doctors, high-tech machinery needing experts to

run it, middle-skilled nurse practitioners, and low-skilled people working in the cafeteria."

However, he continues, the trends of recent times have been disturbing: "The inequality and stagnation of incomes for 75 to 85 percent of ordinary Americans is a massive problem." Without income mobility and more investment in education, America could become a permanently stratified society. "Hence, the central issue confronted by Obama's economic program is, How do we address the squeeze on ordinary Americans? Because the barriers could become impermeable."

CREATIVE DESTRUCTION

"In 1910," Goolsbee says, "if someone could have gone back and told people then how many phone lines would exist today in the U.S., they'd have responded that that was physically impossible, because every American would need to be a telephone exchange operator. That few switchboard operators exist today, nevertheless, isn't a sign that all those people are unemployed. The labor economist Alan Krueger at Princeton has studied what share of the highest-paying occupations are occupation codes that didn't exist in the 1980 census. The figure is very substantial. There's always job churn." Continual job destruction and creation, Goolsbee insists, is healthy.

Where might future jobs come from, though? "There's a joke within economics that 40 years from now every economist will be a health-care economist, because if you simply extrapolate from the current trend, the whole economy will be health care." While we currently think of health care as a cost of business, Goolsbee continues, he can imagine it becoming a central driver of the economy. "Firstly, these are great engines of growth. Secondly, they make us healthy—and what's better than that? Spending on medical research and science, by any crass economic calculation, has a massive payoff, because if you put any value on life—for instance, if you've medicine that keeps people alive for an extra two years—the implicit value of that is great. I could *easily* see some emerging combination of medical science, biotechnology, and computing as the foundation of much of our economic growth going forward."

Goolsbee pauses, then says: "That's why the last eight years' degradation of the budgets for science and its general politicization are so upsetting. The government's commitment to investment in advanced training of our own people has plummeted, so now something like two-thirds of those gaining science and engineering PhDs here aren't U.S. citizens. For many years America led globally in the percentage of 25-year-olds with college degrees. Now the U.S. is 31 in the world—right behind Bulgaria and right above Costa Rica. The problem for countries with skill levels between Bulgaria and Costa Rica is that 20 years from now they'll also have income levels between those countries."

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I Just Called to Say I Love You"

CELL PHONES. SENTIMENTALITY. AND THE DECLINE OF PUBLIC SPACE By JONATHAN FRANZEN

ne of the great irritations of modern technology is that when some new development has made my life palpably worse and is continuing to find new and different ways to be evil it, I'm still allowed to complain for only a year or two before the peddlers of coolness start telling me to get over it already Grampaw-this is just the way life is now.

I'm not opposed to technological developments. Digital voice mail and caller ID, which together destroyed the tyranny of the ringing telephone, seem to me two of the truly great inventions of the late 20th century. And how I love my Black-Berry, which lets me deal with lengthy, unwelcome e-mails in a few breathless telegraphic lines for which the recipient is nevertheless obliged to feel grateful, because I did it with my thumbs. And my noise-canceling headphones, on which I can blast frequency-shifted white noise ("pink noise") that drowns out even the most determined woofing of a neighbor's television set: I love them. And the whole wonderful world of DVD technology and high-definition screens, which have already spared me from so many sticky theater floors, so many rudely whispering cinema-goers, so many open-mouthed crunchers of popcorn: yes.

Privacy, to me, is not about keeping my personal life hidden from other people. It's about sparing me from the intrusion of other people's personal lives. And so, although my very favorite gadgets are actively privacy enhancing, I look kindly on pretty much any development that doesn't force me to interact with it. If you choose to spend an hour every day tinkering with your Facebook profile, or if you don't see any difference between reading Jane Austen on a Kindle and reading her on a printed page, or if you think Grand Theft Auto IV is the greatest Gesamtkunstwerk since Wagner, I'm very happy for you, as long as you keep it to yourself.

The developments I have a problem with are the insults that keep on insulting, the injuries of yesteryear that keep on giving pain. Airport TV, for example: it seems to be actively watched by about one traveler in ten (unless there's football on) while creating an active nuisance for the other nine. Year after year; in airport after airport; a small but apparently permanent diminution in the quality of the average traveler's life. Or, another example, the planned obsolescence of great software and its replacement by bad software. I'm still unable to accept that the best word-processing program ever written, WordPerfect 5.0 for DOS, won't even run on any computer I can buy now. Oh, sure, in theory you can still run it in Windows' little DOS-emulating window, but the tininess and graphical crudeness of that emulator are like a deliberate insult on Microsoft's part to those of us who would prefer not to use a feature-heavy behemoth. WordPerfect 5.0 was hopelessly primitive for desktop publishing but unsurpassable for writers who wanted only to write. Elegant, bug-free, negligible in size, it was bludgeoned out of existence by the obese, intrusive, monopolistic, crash-prone Word. If I hadn't been collecting old 386s and 486s in my office closet, I wouldn't be able to use WordPerfect at all by now. And already I'm down to my last old 486. And yet people have the nerve to be annoyed with me if I won't send them texts in a format intelligible to all-powerful Word. We live in a Word world now, Grampaw. Time to take your GOI pill.

But these are mere annoyances. The technological development that has done lasting harm of real social significance—the development that, despite the continuing harm it does, you risk ridicule if you publicly complain about today-is the cell phone.

Just 10 years ago, New York City (where I live) still abounded with collectively maintained public spaces in which citizens



demonstrated respect for their community by not inflicting their banal bedroom lives on it. The world 10 years ago was not yet fully conquered by yak. It was still possible to see the use of Nokias as an ostentation or an affectation of the affluent. Or, more generously, as an affliction or a disability or a crutch. There was unfolding, after all, in New York in the late 1990s, a seamless citywide transition from nicotine culture to cellular culture. One day the lump in the shirt pocket was Marlboros, the next day it was Motorola. One day the vulnerably unaccompanied pretty girl was occupying her hands and mouth and attention with a cigarette, the next day she was occupying them with a very important conversation with a person who wasn't you. One day a crowd gathered around the first kid on the playground with a pack of Kools, the next day around the first kid with a color screen. One day travelers were clicking lighters the second they were off an airplane, the next day they were speed-dialing. Pack-a-day habits became hundred-dollar monthly Verizon bills. Smoke pollution became sonic pollution. Although the irritant changed overnight, the suffering of a self-restrained majority at the hands of a compulsive minority, in restaurants and airports and other public spaces, remained eerily constant. Back in 1998, not long after I'd quit cigarettes, I would sit on the subway and watch other riders nervously folding and unfolding phones, or nibbling on the teatlike antennae that all the phones then had, or just quietly clutching their devices like a mother's hand, and I would feel something close to sorry for them. It still seemed to me an open question how far the trend would go: whether New York truly wanted to become a city of phone addicts sleepwalking down the sidewalks in icky little clouds of private life, or whether the notion of a more restrained public self might somehow prevail.

Needless to say, there wasn't any contest. The cell phone wasn't one of those modern developments, like Ritalin or oversized umbrellas, for which significant pockets of civilian resistance hearteningly persist. Its triumph was swift and total. Its abuses were lamented and bitched about in essays and columns and letters to various editors, and then lamented and bitched about more trenchantly when the abuses seemed only to be getting worse, but that was the end of it. The complaints had been registered, some small token adjustments had been made (the "quiet car" on Amtrak trains; discreet little signs poignantly pleading for restraint in restaurants and gyms), and cellular technology was then free to continue doing its damage without fear of further criticism, because further criticism would be unfresh and uncool. Grampaw.

But just because the problem is familiar to us now doesn't mean steam stops issuing from the ears of drivers trapped behind a guy chatting on his phone in a passing lane and staying perfectly abreast of a vehicle in the slow lane. And yet: everything in our commercial culture tells the chatty driver that he is in the right and tells everybody else that we are in the wrong—that we are failing to get with the attractively priced program of freedom and mobility and unlimited minutes. Commercial culture tells us that if we're sore with the chatty driver it must be because we're not having as good a time as he is. What is wrong with us, anyway? Why can't we lighten up a little and take out our own phones, with our own Friends and Family plans, and start having a better time ourselves, right there in the passing lane?

Socially retarded people don't suddenly start acting more adult when social critics are peer-pressured into silence. They only get ruder. One currently worsening national plague is the shopper who remains engrossed in a call throughout a transaction with a checkout clerk. The typical combination in my own neighborhood, in Manhattan, involves a young white woman, recently graduated from someplace expensive, and a local black or Hispanic woman of roughly the same age but fewer advantages. It is, of course, a liberal vanity to expect your checkout clerk to interact with you or to appreciate the scrupulousness of your determination to interact with her. Given the repetitive and low-paying nature of her job, she's allowed to treat you with boredom or indifference; at worst, it's unprofessional of her. But this does not relieve you of your own moral obligation to acknowledge her existence as a person. And while it's true that some clerks don't seem to mind being ignored, a notably large percentage do become visibly irritated or angered or saddened when a customer is unable to tear herself off her phone for even two seconds of direct interaction. Needless to say, the offender herself, like the chatty freeway driver, is blissfully unaware of pissing anybody off. In my experience, the longer the line behind her, the more likely it is she'll pay for her \$1.98 purchase with a credit card. And not the tap-and-go microchip kind of credit card, either, but the wait-for-the-printed-receipt-and-then-(only then)with-zombiesh-clumsiness-begin-shifting-the-cell-phonefrom-one-ear-to-the-other-and-awkwardly-pin-the-phone-withear-to-shoulder-while-signing-the-receipt-and-continuingto-express-doubt-about-whether-she-really-feels-like-meetingup-with-that-Morgan-Stanley-guy-Zachary-at-the-Etats-Uniswine-bar-again-tonight kind of credit card.

There is, to be sure, one positive social consequence of these worsening misbehaviors. The abstract notion of civilized public spaces, as rare resources worth defending, may be all but dead, but there's still consolation to be found in the momentary ad hoc microcommunities of fellow sufferers that bad behaviors create. To look out your car window and see the steam coming out of another driver's ears, or to meet the eyes of a pissed-off checkout clerk and to shake your head along with her: it makes you feel a little less alone.

Which is why, of all the worsening varieties of bad cell-phone behavior, the one that most deeply irritates me is the one that seems, because it is ostensibly victimless, to irritate nobody else. I'm talking about the habit, uncommon to years ago, now ubiquitous, of ending cell-phone conversations by braying the words "LOVE YOU!" Or, even more oppressive and grating: "I LOVE YOU!" It makes me want to go and live in China, where I don't understand the language. It makes me want to scream.

The cellular component of my irritation is straightforward. I simply do not, while buying socks at the Gap, or standing in a ticket line and pursuing my private thoughts, or trying to read a novel on a plane that's being boarded, want to be imaginatively drawn into the sticky world of some nearby human being's home life. The very essence of the cell phone's

for other people so common and routine and easily achieved that it can be reëxperienced and reëxpressed many times in a single day without significant loss of power.

It's also possible, however, that too-frequent habitual repetition empties phrases of their meaning. Joni Mitchell, in the last verse of "Both Sides Now," referenced the solemn amazement of saying I love you "right out loud": of giving vocal birth to such intensity of feeling. Stevie Wonder, in lyrics written 17 years later, sings of calling somebody up on an ordinary afternoon simply to say "I love you," and being Stevie Wonder (who probably really is a more loving person than I am), he half succeeds in making me believe in his sincerity—at least until the last line of the chorus, where he finds it necessary to add: "And I mean it from the bottom of my heart." No such avowal is thinkable for the person who really does mean something from the bottom of his heart.

When I'm buying those socks at the Gap and the mom in line behind me shouts "I love you!" into her little phone, I am powerless not to feel that something is being performed; overperformed; publicly performed; defiantly inflicted.

hideousness, as a social phenomenon—the bad news that stays bad news—is that it enables and encourages the inflicting of the personal and individual on the public and communal. And there is no higher-caliber utterance than "I love you"—nothing worse that an individual can inflict on a communal public space. Even "Fuck you, dickhead" is less invasive, since it's the kind of thing that angry people do sometimes shout in public, and it can just as easily be directed at a stranger.

My friend Elisabeth assures me that the new national plague of love yous is a good thing: a healthy reaction against the repressed family dynamics of our Protestant childhoods some decades ago. What could be wrong, Elisabeth asks, with telling your mother that you love her, or with hearing from her that she loves you? What if one of you dies before you can speak again? Isn't it nice that we can say these things to each other so freely now?

I do here admit the possibility that, compared with everyone else on the airport concourse, I am an extraordinarily cold and unloving person; that the sudden overwhelming sensation of *loving* somebody (a friend, a spouse, a parent, a sibling), which to me is such an important and signal sensation that I'm at pains not to wear out the phrase that best expresses it, is

And, just so, when I'm buying those socks at the Gap and the mom in line behind me shouts "I love you!" into her little phone, I am powerless not to feel that something is being performed; overperformed; publicly performed; defiantly inflicted. Yes, a lot of domestic things get shouted in public which really aren't intended for public consumption; yes, people get carried away. But the phrase "I love you" is too important and loaded, and its use as a sign-off too self-conscious, for me to believe I'm being made to hear it accidentally. If the mother's declaration of love had genuine, private emotional weight, wouldn't she take at least a little care to guard it from public hearing? If she truly meant what she was saying, from the bottom of her heart, wouldn't she have to say it quietly? Overhearing her, as a stranger, I have the feeling of being made party to an aggressive assertion of entitlement. At a minimum, the person is saying to me and to everyone else present: "My emotions and my family are more important to me than your social comfort." And also, often enough, I suspect: "I want you all to know that unlike many people, including my cold bastard of a father, I am the kind of person who always tells my loved ones that I love them."

Or am I, in my admittedly now rather lunatic-sounding irritation, simply projecting all this?

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The cell phone came of age on September II, 2001. Imprinted that day on our collective consciousness was the image of cell phones as conduits of intimacy for the desperate. In every too-loud I love you that I hear nowadays, as in the more general national orgy of connectedness—the imperative for parents and children to connect by phone once or twice or five or ten times daily—it's difficult not to hear an echo of those terrible, entirely appropriate, heartbreaking I love yous uttered on the four doomed planes and in the two doomed towers. And it's precisely this echo, the fact that it's an echo, the sentimentality of it, that so irritates me.

My own experience of g/II was anomalous for the lack of television in it. At nine in the morning, I got a phone call from my book editor, who, from his office window, had just seen the second plane hit the towers. I did immediately go to the nearest TV, in the conference room of the real-estate office downstairs from my apartment, and watch with a group of agents as first one tower and then the other went down. But then my girlfriend came home and we spent the rest of the day listening to the radio, checking the Internet, reassuring our families, and watching from our roof and from the middle of Lexington Avenue (which was filled with pedestrians streaming uptown) as the dust and smoke at the bottom of Manhattan diffused into a sickening pall. In the evening, we walked down to 42nd Street and met up with an out-of-town friend and found an unremarkable Italian restaurant in the West 40s which happened to be serving dinner. Every table was packed with people drinking heavily; the mood was wartime. I got another brief glimpse of a TV screen, this one showing the face of George W. Bush, as we were departing through the restaurant's bar. "He looks like a scared mouse," somebody said. Sitting on a 6 train at Grand Central, waiting for it to move, we watched a New York commuter angrily complain to a conductor about the lack of express service to the Bronx.

Three nights later, from 11:00 P.M. to nearly 3:00 A.M., I sat in a frigid room at ABC News from which I could see my fel-

low New Yorker David Halberstam and speak by video link to Maya Angelou and a couple of other out-of-town writers while we waited to offer Ted Koppel a literary perspective on Tuesday morning's attacks. The wait was not short. Footage of the attacks and the ensuing collapses and fires was shown again and again, interspersed with long segments on the emotional toll on ordinary citizens and their impressionable children. Every once in a while, one or two of us writers would have 60 seconds to say something writerly before the coverage reverted to more carnage and wrenching interviews with friends and family of the dead and the missing. I spoke four times in three and a half hours. The second time, I was asked to confirm widespread reports that Tuesday's attacks had profoundly changed the personality of New Yorkers. I could not confirm these reports. I said that the faces I had seen were somber, not angry, and I described seeing people shopping in the stores in my neighborhood on Wednesday afternoon, buying fall clothes. Ted Koppel, in his response, made clear that I'd failed at the task I'd been waiting half the night to perform. With a frown, he said that his own impression was very different: that the attacks had indeed profoundly changed the personality of New York City.

Naturally, I assumed that I was speaking truth and Koppel merely retransmitting received opinion. But Koppel had been watching TV and I had not. I didn't understand that the worst damage to the country was being done not by the pathogen but by the immune system's massive overresponse to it, because I didn't have a TV. I was mentally comparing Tuesday's death toll with other tallies of violent death—3,000 Americans killed in traffic accidents in the 30 days preceding September II—because, not seeing the images, I thought the numbers mattered. I was devoting energy to imagining, or resisting imagining, the horror of sitting in a window seat while your plane came in low along the West Side Highway, or of being trapped on the 95th floor and hearing the steel structure below you begin to groan and rumble, while the rest of the country was experiencing actual real-time trauma by watching the same footage over and over. And so I was



not in need of—was, for a while, not even aware of—the national televised group therapy session, the vast techno-hugathon, that unfolded in the following days and weeks and months in response to the trauma of exposure to televised images.

What I could see was the sudden, mysterious, disastrous sentimentalization of American public discourse. And just as I can't help blaming cellular technology when people pour parental or filial affection into their phones and rudeness onto every stranger within earshot, I can't help blaming media technology for the national foregrounding of the personal. Unlike in, say, 1941, when the United States responded to a terrible attack with collective resolve and discipline and sacrifice, in 2001 we had terrific visuals. We had amateur footage and could break it down frame by frame. We had screens to bring the violence raw into every bedroom in the country, and voice mail to record the desperate final calls of the doomed, and late-model psychology to explicate and heal our trauma. But as for what the attacks actually signified, and what a sensible response to them might look like, attitudes varied. This was the wonderful thing about digital technology: No more hurtful censoring of anybody's feelings! Everybody entitled to express his or her own opinion! Whether or not Saddam Hussein had personally bought plane tickets for the hijackers therefore remained open to lively debate. What everybody agreed to agree on, instead, was that the families of 9/11's victims had a right to approve or veto plans for the memorial at Ground Zero. And everybody could share in the pain experienced by the families of the fallen cops and firefighters. And everybody agreed that irony was dead. The bad, empty irony of the 'gos was simply "no longer possible" post-9/11; we'd stepped forward into a new age of sincerity.

On the plus side, Americans in 2001 were a lot better at saying "I love you" to their children than their fathers or grandfathers had been. But competing economically? Pulling together as a nation? Defeating our enemies? Forming strong international alliances? Perhaps a bit of a minus side there.

y parents met two years after Pearl Harbor, in the fall of 1943, and within a few months they were exchanging cards and letters. My father worked for the Great Northern Railway and was often on the road, in small towns, inspecting or repairing bridges, while my mother stayed in Minneapolis and worked as a receptionist. Of the letters from him to her in my possession, the oldest is from Valentine's Day 1944. He was in Fairview, Montana, and my mother had sent him a Valentine's card in the style of all her cards in the year leading up to their marriage: sweetly drawn babies or toddlers or baby animals voicing sweet sentiments. The front of her valentine (which my father likewise saved) shows a pigtailed little girl and a blushing little boy standing beside each other with their eyes bashfully averted and their hands tucked bashfully behind their backs.

I wish I were a little rock, 'Cause then when I grew older, Maybe I would find some day I was a little "boulder."

Inside the card is a drawing of the same two kids, but holding hands now, with my mother's cursive signature ("Irene") at the feet of the little girl. A second verse reads:

And that would really help a lot It sure would suit me fine, For I'd be "bould" enough to say, "Please be my Valentine."

My father's letter in response was postmarked Fairview, Montana, February 14.

Tuesday Evening

Dear Irene,

I'm sorry to have disappointed you on Valentine's Day; I did remember but after not being able to get one at the drugstore, I felt a little foolish about asking at the grocery or hardware store. I'm sure they have heard about Valentine's Day out here. Your card fit the situation out here perfectly and I'm not sure if it were intentional or accidental, but I guess I did tell about our rock troubles. Today we ran out of rock so I'm wishing for little rocks, big rocks or any kind of rocks as there is nothing we can do until we get some. There is little enough for me to do when the contractor is working and now there is nothing at all. Today I hiked out to the bridge where we are working just to kill time and get a little exercise; it's about four miles which is far enough with a sharp wind blowing. Unless we get rock on the freight in the morning, I'm going to sit right here and read philosophy; it hardly seems right that I should get paid for putting in that kind of day. About the

WWW.TECHNOLOGYREVIEW.COM ESSAY 93

only other pastime around here is to sit in the hotel lobby and take in the town gossip, and the old timers who haunt the place can sure put it out. You would get a kick out of it because there is sure a broad cross section of life represented here—from the local doctor down to the town drunk. And the last is probably the most interesting; I heard that he taught at the University of N.D. at one time, and he seems really to be quite an intelligent person, even when drunk. Normally the talk is pretty rough, about like Steinbeck must have used for a pattern, but this evening there came in a great big woman who made herself right at home. It all sort of makes me realize how sheltered a life we city people live. I grew up in a small town and feel quite at home here but I somehow now seem to view things differently. You will hear more of this.

I hope to get back to St. Paul on Saturday night but cannot tell for certain now. I'll call you when I get in.

With all my love,

Earl

My father had recently turned 29. It's impossible to know how my mother, in her innocence and optimism, received his letter at the time, but in general, considering the woman I grew up knowing, I can say that it was absolutely not the sort of letter she would have wanted from her romantic interest. Her valentine's cutely punning conceit taken literally as a reference to *track ballast?* And she, who spent her whole life shuddering free of the hotel bar where her father had worked as a bartender, *getting a kick out of* hearing "rough talk" from the *town drunk?* Where were the endearments? Where were the dreamy discussions of love? It was obvious that my father still had a lot to learn about her.

To me, though, his letter seems full of love. Love for my mother, certainly: he's tried to get her a valentine, he's read her card carefully, he wishes she were with him, he has ideas he wants to share with her, he's sending all his love, he'll call her as soon as he's back. But love, too, for the larger world: for the varieties of people in it, for small towns and big cities, for philosophy and literature, for hard work and fair pay, for conversation, for thinking, for long walks in a sharp wind, for carefully chosen words and perfect spelling. The letter reminds me of the many things I loved in my father, his decency, his intelligence, his unexpected humor, his curiosity, his conscientiousness, his reserve and dignity. Only when I place it alongside the valentine from my mother, with its big-eyed babies and preoccupation with pure sentiment, does my focus shift to the decades of mutual disappointment that followed my parents' first few years of half-seeing bliss.

Late in life, my mother complained to me that my father had never told her that he loved her. And it may literally be

true that he never spoke the big three words to her—I certainly never heard him do it. But it's definitely not true that he never wrote the words. One reason it took me years to summon the courage to read their old correspondence is that the first letter of my father's that I glanced at, after my mother died, began with an endearment ("Irenie") that I had never heard him utter in the 35 years I knew him, and it ended with a declaration ("I love you, Irene") that was more than I could stand to see. It sounded nothing like him, and so I buried all the letters in a trunk in my brother's attic. More recently, when I retrieved the letters and managed to read through them all, I discovered that my father had in fact declared his love dozens of times, using the big three words, both before and after he married my mother. But maybe, even then, he'd been incapable of saying the words out loud, and maybe this was why, in my mother's memory, he'd never "said" them at all. It's also possible that his written declarations had sounded as strange and untrue to his character in the 1940s as they now sound to me, and that my mother, in her complaints, was remembering a deeper truth now concealed by his seemingly affectionate words. It's possible that, in guilty response to the onslaught of sentiment he was getting from her notes to him ("I love you with all my heart," "With oh so much love," etc.), he'd felt obliged to perform romantic love in return, or to try to perform it, the way he'd tried (sort of) to buy a valentine in Fairview, Montana.

"Both Sides Now," in the Judy Collins version, was the first pop song that ever stuck in my head. It was getting heavy radio play when I was eight or nine, and its reference to declaring love "right out loud," combined with the crush I had on Judy Collins's voice, helped to ensure that for me the primary import of "I love you" was sexual. I did eventually live through the '70s and become capable, in rare accesses of emotion, of telling my brothers and many of my best male friends that I loved them. But throughout grade school and junior high, the words had only one meaning for me. "I love you" was the phrase I wanted to see scrawled on a note from the cutest girl in the class or to hear whispered in the woods on a school picnic. It happened only a couple of times, in those years, that a girl I liked actually said or wrote this to me. But when it did happen, it came as a shot of pure adrenaline. Even after I got to college and started reading Wallace Stevens and found him making fun, in "Le Monocle de Mon Oncle," of indiscriminately love-seeking people like me-

If sex were all, then every trembling hand Could make us squeak, like dolls, the wished-for words—

—those wished-for words continued to signify the opening of a mouth, the offering of a body, the promise of intoxicating intimacy.

And so it was highly awkward that the person I constantly heard these words from was my mother. She was the only woman in a house of males, and she lived with such an excess of unrequitable feeling that she couldn't help reaching for romantic expressions of it. The cards and endearments that she bestowed on me were identical in spirit to the ones she'd once bestowed on my father. Long before I was born, her effusions had come to seem intolerably babyish to my father. To me, though, they weren't nearly babyish enough. I went to elaborate lengths to avoid reciprocating them. I survived many stretches of my childhood, the long weeks in which the two of us were alone in the house together, by clinging to crucial distinctions in intensity between the phrases "I love you"; "I love you, too"; and "Love you." The one thing that was vital was never, ever to say "I love you" or "I love you, Mom." The least painful alternative was a muttered, essentially inaudible "Love you." But "I love you, too," if pronounced rapidly enough

had greater scope for accomplishment, she might have tailored her sentiments more realistically to their objects.

Cold or repressed or sexist though my father may appear by contemporary standards, I'm grateful that he never told me, in so many words, that he loved me. My father loved privacy, which is to say: he respected the public sphere. He believed in restraint and protocol and reason, because without them, he believed, it was impossible for a society to debate and make decisions in its best interest. It might have been nice, especially for me, if he'd learned how to be more demonstrative with my mother. But every time I hear one of those brayed parental cellular I love yous nowadays, I feel lucky to have had the dad I did. He loved his kids more than anything. And to know that he felt it and couldn't say it; to know that he could trust me to know he felt it and never expect him to say it: this was the very core and substance of the love I felt for him. A love that I in turn was careful never to declare out loud to him.

My father loved privacy, which is to say: he respected the public sphere. He believed in restraint and protocol and reason, because without them, he believed, it was impossible for a society to debate and make decisions in its best interest.

and with enough emphasis on the "too," which implied rote responsiveness, could carry me through many an awkward moment. I don't remember that she ever specifically called me out on my mumbling or gave me a hard time if (as sometimes happened) I was incapable of responding with anything more than an evasive grunt. But she also never told me that saying "I love you" was simply something she enjoyed doing because her heart was full of feeling, and that I shouldn't feel I had to say "I love you" in return every time. And so, to this day, when I'm assaulted by the shouting of "I love you" into a cell phone, I hear coercion.

My father, despite writing letters filled with life and curiosity, saw nothing wrong with consigning my mother to four decades of cooking and cleaning at home while he was enjoying his agency out in the world of men. It seems to be the rule, in both the small world of marriage and the big world of American life, that those without agency have sentimentality and vice versa. The various post-9/11 hysterias, both the plague of I love yous and the widespread fear and hatred of the ragheads, were hysterias of the powerless and overwhelmed. If my mother had

And yet: this was the easy part. Between me and the place where my dad is now-i.e., dead-nothing but silence can be transmitted. Nobody has more privacy than the dead. My dad and I aren't saying a whole lot less to each other now than we did in many a year when he was alive. The person I find myself actively missing-mentally arguing with, wanting to show stuff to, wishing to see in my apartment, making fun of, feeling remorse about—is my mother. The part of me that's angered by cellular intrusions comes from my father. The part of me that loves my BlackBerry and wants to lighten up and join the world comes from my mother. She was the more modern of the two of them, and although he, not she, was the one with agency, she ended up on the winning side. If she were still alive and still living in St. Louis, and if you happened to be sitting next to me in Lambert Airport, waiting for a New York-bound flight, you might have to suffer through hearing me tell her that I love her. I would keep my voice down, though. TR

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www.technologyreview.com essay 95

REVIEWS

BLOGGING AND THE INTERNET

It's Not a Revolution if Nobody Loses"

A NEW AGE OF "TECHNOLOGICAL REPRODUCIBILITY" IS HERE. UGH

By EMILY GOULD

Early in Here Comes Everybody: The Power of Organizing without Organizations, Clay Shirky-an Internet scholar at New York University who also profitably shares his expertise with organizations like Nokia, Procter and Gamble, and News Corp.reminds his readers that our moment of rapid, technology-abetted social change is not without historical precedent. The

century-long"chaotic period" that followed the invention of movable type was even more confusing, he says. At one point, things got so weird that an abbot published a defense of the scribal tradition then being eclipsed by the printing press and, because he wanted it disseminated cheaply and efficiently, had it printed rather than having it copied

by the scribes whose livelihoods he was defending.

What would the poor abbot say if he knew that much of what the good old printing press seems to be spitting out these days is books about the technology that ended books' 400year winning streak? Sure, the Internet has been inspiring dead-tree guides to optimizing its power while minimizing its dangers for almost as long as it has existed, but right now this section of the nonfiction shelf is

glutted. From last year's Send, which promised to guide noobs (newbies, for you noobs) through the niceties of e-mail correspondence, to Jonathan Zittrain's warning about the dangers of "tethered appliances" like iPhones, to Lee Siegel's wounded polemic against the culture of online meanness he calls "blogofascism," to linguist Naomi S. Baron's warnings about the way IM totes

compromises expression and comprehension IRL, to Daniel Solove's musings about the YouTube-diminished "future of reputation," publishers are banking on the notion that whenever we're not busy twittering our lives away, we'd like to be reading a pop-scholarly analysis of why we're doing so and how we could be doing it better. Who do they think is

buying these books, anyway?

Actually, come to think of it, I'm buying them-all of them. I'm doing it for odd reasons, though, and I'm looking in them for something that I never quite find. Like an expatriate who reads every new novel that's set in her homeland, I read books about the Internet to remember the time I spent working and living there, to contrast my memories with the authors' impressions and see how well they hold up. In Shirky's descriptions of the way new Web-based social tools are restructuring businesses, communities, and relationships, I recognize familiar scenery. He knows what he's talking about-he's lived there too. You get the sense, though, that he's somehow managed to avoid walking down any dark alleys, or staring too long at any piles of fetid garbage.

The thing is, Internet books are inevitably either cheerleadery or chidey, and Shirky [who writes about open-source Web publishing on page 54 of this issue –Ed.] is a cheerleader. He makes a good case, too, for the rightness of celebrating the ways that blog, wiki, and social-networking technologies have enriched our lives, though he acknowledges that we're losing freedoms as quickly as we're gaining them. "It's not a revolution if nobody loses," he says, and he goes on to describe three kinds of losers: the workers whose industries are undermined by the free dissemination of information they used to control; the journalists who, like those 15thcentury scribes, have lost their professional identity and prestige; and the people who come to harm when "bad groups"-his deftly apolitical and therefore in offensive example is pro-anorexia support groups—are able to assemble and distribute information more easily. In general, however, you get the sense that he doesn't mind sacrificing these losers on the altar of change.

But there is another, larger kind of loss happening, and in order to understand it, we might turn to the tech-trend literature of an earlier era.

In Berlin in the mid-1930s, the German-Jewish Marxist literary and cultural critic Walter Benjamin (who killed himself in 1940,

HERE COMES EVERY-**BODY: THE POWER OF ORGANIZING WITHOUT** ORGANIZATIONS

By Clay Shirky Penguin, 2008, \$25.95

THE WORK OF ART IN THE AGE OF ITS **TECHNOLOGICAL** REPRODUCIBILITY AND OTHER WRITINGS ON MEDIA

By Walter Benjamin Harvard University Press, 2008, \$18.95





MEDIA MARTYR Walter Benajmin believed that modern media permitted a revolution in perception that made us prey to dictators and false gods. He might have been talking about Facebook.

lest the Nazis have that pleasure) wrote a sprawling yet intensely epigrammatic essay called "The Work of Art in the Age of Its Technological Reproducibility," which is assigned in order to confuse nearly every college student who takes a comp-lit class in America today. Freshly translated (it used to be called "The Work of Art in the Age of Mechanical Reproduction," which, although more lumberingly Teutonic, has the virtue of evoking an image of robot sex) and newly packaged with an assortment of his other "writings on media" in a hipsterfriendly paperback, Benjamin's best-known work is ... well, as they say on Facebook, it's complicated. Man, is it ever complicated. The essay begins by describing the ways

film and photography have changed human perception. Benjamin argues that because such exact simulacra of reality can be mass-distributed and mass-consumed, we have a new, more distant relationship to authentic reality—and he concludes that these changes in perception clear a path for fascism.

Not exactly cheerleadery, then. And while it's easy to be distracted by Benjamin's dusty examples—Chaplin's films and Picasso's paintings—and therefore lulled into thinking he's describing a different world from Shirky's ... well, don't be. Substitute blogs and social-networking platforms and Twitter and YouTube and Wikipedia for film and photography, and the nearly century-old essay becomes a relevant, piercing alarm.

In celebrating the tools we're all thoughtlessly adopting, Shirky ably demonstrates how useful they are in allowing us to share our common interests and keep track of each other's whereabouts. Thousands of Xena: Warrior Princess fans, previously unknown to each other, are uniting at Internet-organized meetups. Text-message blogging platform Twitter, normally just a way of bragging about the party you're currently attending in real time, can become a tool of dissent if you happen to become a political prisoner (and somehow manage to hang onto your phone, as an activist blogger recently did in Cairo). Shirky even believes that technology is creating and enabling "love"; when he talks about the hundreds of thousands of people who are collaboratively building Wikipedia, he says they "love one another in its context." He fails to mention-or maybe he fails to notice-that the "love" and "freedom" he describes don't mean quite what they did back when our meat acquaintances outnumbered our Facebook "friends."

Maybe, in the same way that Benjamin says the difference between "follow[ing] with the eye, while resting on a summer afternoon, a mountain range on the horizon" and experiencing that same mountain range at a remove (imagine a picture postcard) makes it harder to appreciate the real thing ("Gosh, this mountain is beautiful! Just like a postcard!"), social-media technologies are creating simulacra of social connection, facsimiles of friendship. By ignoring that difference, as Shirky mostly does, we keep moving heedlessly toward a future where the basic human social activities that these new technologies are modeled on-talking, being introduced to new people by friends-are threatened.

These concerns probably aren't foremost in the minds of Shirky's readers, who are probably just trying to figure out how to wield more influence in the new world he describes. But it's worth thinking about the kind of book that Shirky, a lucid enough thinker and writer, would compose if he

WWW.TECHNOLOGYREVIEW.COM REVIEWS 97

were more concerned with the uses of online "love" and "freedom."

And if we're concerned about that, what can we do? What would Benjamin do, besides worry about what's lost every time a Tumblr post is reblogged?

Here's something to try as (trust me!) a pointless experiment: cease to log in to your instant messenger for a week. You'll find out quickly that for some of the "buddies" on your buddy list, you immediately cease, for all intents and purposes, to exist. Or go one step further: delete your profile from Face-

TRY THIS AS A POINT-LESS EXPERIMENT: CEASE TO LOG IN TO YOUR INSTANT MESSENGER FOR A WEEK. YOU'LL FIND **OUT QUICKLY THAT** FOR SOME OF THE "BUDDIES" ON YOUR **BUDDY LIST. YOU** CEASE TO EXIST.

book and stop blogging. Stop reading blogs. Stop attending social events you find out about online. See how your world shrinks, and if you're brave, see if you can stick with your foray into social-media abstention until you start to see your world opening back up again-maybe in different ways.

Temporarily pretending that the world hasn't changed may be instructive, but it is neither Shirkian nor Benjaminian. As Walter Benjamin probably wouldn't put it, there's no point in clinging to what used to seem to be real. But I'm still waiting for the author who, without being like the guy who defended scribes in print, finds a way to say that we shouldn't let this stuff run amok just because it can and it wants to. Because it does want to.

EMILY GOULD WAS AN EDITOR AT GAWKER.COM FROM SEPTEMBER 2006 TO NOVEMBER 2007. IN MAY, SHE WROTE A COVER STORY, "EXPOSED," FOR THE NEW YORK TIMES MAGAZINE ABOUT HER TIME BLOGGING FOR GAWKER. FREE PRESS WILL PUBLISH HER FIRST BOOK-OF AUTOBIOGRAPHICAL STORIES-IN 2010. DNA

Personal Genomics: Access Denied?

EVEN IF WE CAN'T INTERPRET THE DATA. CONSUMERS HAVE A RIGHT TO THEIR GENOMES

By MISHA ANGRIST

n April, a startup company called Navigen-Lics threw a swanky 10-day celebration in lower Manhattan to launch its highly publicized personal-genomics service, which offers genetic risk assessments for 21 complex health conditions-such as heart attack and diabetes-that are partly mediated by multiple genes. (I received complimentary genotyping from Navigenics; it normally costs \$2,500.) Unbeknownst to attendees, the New York State Department of Health

had sent a warning letter a few days earlier to the company and 22 others that offer similar products, telling them that they needed a permit before they could sell their services. New York-based party goers would be unable to partake in Navigenics' testing.

Indeed, both Navigenics and its main competitors-California's 23andMe and Iceland's deCode-have faced a stern backlash from health experts and regulators. All three companies use gene chip technology to scan an individual's genome, at a cost of \$1,000 to \$2,500, for variations that have been linked to diseases or to traits such as eye color and muscle strength. Understanding their risk for a disease, says Navigenics cofounder Dietrich Stephan, allows people to make plans, take preventive steps by altering their lifestyles (exercising and keeping the brain active, for example), and stay informed about new therapies. But making such tests available directly to consumers over the Internet, as these companies do, has aroused concern in both scientific and public-health circles. In their disclaimers, all three say that they are not offering medical advice or practicing medicine. But critics say that it's not just medicine, it's bad medicine.

In January, the New England Journal of Medicine outlined major concerns in an editorial titled "Letting the Genome Out of the Bottle." The tests, the journal charged, are not clinically validated-meaning that it's not clear exactly how predictive their results will be. What's more, a consumer who discovers a risk for a disease may not be able to do anything about it. The test

> results could lead to unnecessary anxiety-or, worse, to false confidence. Someone whose test indicates no predisposition to diabetes, for example, might abandon efforts to diet and exercise. In short, the journal concluded, doctors should tell patients that the information derived

from these services is essentially useless and that people interested in their genetic data should "ask again in a few years."

In June, California followed New York's lead and sent cease-and-desist letters to 13 companies, including Navigenics, 23 and Me, and deCode. The state complained that companies should not offer their tests directly to consumers without a physician's order; they were, according to an official at the California Department of Public Health, "scaring a lot of people to death." A few of the companies claimed to be in compliance with state law. Others stopped offering their services in California, at least temporarily.

The authorities' reaction is both wrongheaded and arrogant. Whatever their shortcomings (and they have plenty), these companies will not vanish. In a survey commissioned by the Personal Genome Project-

"LETTING THE GENOME OUT OF THE BOTTLE-WILL WE GET OUR WISH?"

By David J. Hunter, Muin J. Khoury, and Jeffrev M. Drazen New England Journal of Medicine, January 10, 2008

CALIFORNIA BUSINESS AND PROFESSIONS **CODE, SECTION 1288**

a nonprofit effort led by Harvard University geneticist George Church, which seeks to better understand the relationship between genetic variation and human health-the vast majority of respondents were interested in gaining access to their genetic information. The National Geographic Society's Genographic Project, a global research study using genetics to shed light on ancient human migration, far exceeded its publicparticipation goals: 250,000 people signed up and paid \$100 each for coarse-grained views of their genetic ancestry, compared with initial expectations of 100,000. We know that people want their genomic data; we need to learn why they want it, what they expect from it, and how they believe it should and shouldn't be regulated.

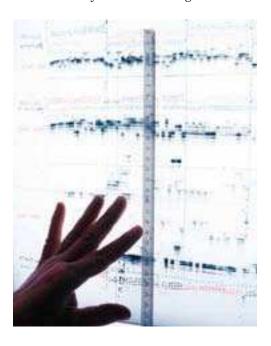
George Church says that regulators' fixation on the relation between personalgenomics companies and medicine is misguided. "If you're interested in medicine, you should talk to your doctor," he says. "But if you're interested in seeing a revolution close up and participating in research, then you should [be free to] mess around. The other thing I don't understand is this: what kind of person is 'scared to death' by a test he went out of his way to get?"

Commercial personal genomics has some real limitations. The validity of the tests will probably take years to sort out; determining how well they measure what they're supposed to measure is not a trivial exercise. And personal genomics can indeed generate real anxiety. Here I speak from experience. I'm a participant in Church's Personal Genome Project, which in its initial phase is working to partially sequence the genomes of 10 volunteers and make their genetic and medical information publicly available. I'll soon learn the sequence of all my more than 20,000 genes.

In the meantime, I've already received data on 500,000 of my genomic markers-specific genetic variations that can be detected with microarrays rather than sequencing. Eager for a quick-anddirty analysis of what they meant, I sent

them to a low-budget single-nucleotidepolymorphism analyzer, SNPedia. SNPedia is a wiki-based website intended to foster communication about genetic variants and let motivated early-adopter types begin to parse their meaning. From it I received-at no cost—a report annotating 270 markers from my genome.

That turned out to be more than enough to confuse and agitate me. Do bad versions of four risk genes for multiple sclerosis add up to four times the risk? What is "exfoliation glaucoma," anyway? It took a few days, but I got over it-probably because we still don't know very much about the genome,



so I didn't put much stock in my genotypes and what traits they were supposed to be associated with. My scan did not reveal any devastating single-gene conditions (although in fairness, it was not designed to); I am fortunate enough to have group health insurance; and I tend to be much more concerned with making it through the day than with whatever genomic time bombs I may carry.

Several studies have shown that disclosing genetic-risk information, especially probabilistic risk information attached

to complex problems like heart disease, Alzheimer's, and cancer, very rarely provokes an end-of-the-world response. Indeed, the results of genetic tests can often seem mundane. The complaint I've heard from some geneticists is that the advice offered by personal-genomics companies amounts to common sense: "Eat right, exercise, don't smoke, lose weight, yadda yadda." Obviously, you don't need to drop a grand to get that kind of advice.

But I would argue that it doesn't matter. As a participant in the Personal Genome Project, I've been asked more than once, "So ... what will you do with your genome?"

> I have two boring stock answers, at least for now: not much, and I don't know. But I do want to learn about my genome. I see personal genomics as akin to the first personal computers. What could we actually do with the Commodore 64 or the Apple II? Word-process? Occasionally. A bit of Lotus 1-2-3? I guess. Mostly, I remember software crashes and hardware freezes. In my house we managed to play a lot of solitaire and Minesweeper.

> This is where we are in the era of personal genomics: some modest amusement, a few interesting tidbits, a bit of useful information, but mostly the promise of much better things to come. The more people are allowed-encouraged, even-to experiment, the sooner that prom-

ise can be realized.

It's time for physicians, scientists, and regulators to write themselves a prescription for reality. After years of excited promises about the various medical miracles that would be wrought by the completion of the Human Genome Project, now we are told by some that delivery of our personal genomic information ought not to be among them, at least not yet. But it's too late for that.

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SOFTWARE

Web App Writers: Rejoice, Beware

ENGINE IS EASY TO USÉ AND-AT LEAST INITIALLY-FREE. IS IT TOO GOOD TO BE TRUE?

GOOGLE APP ENGINE

release since April 2008

code.google.com/

appengine Available in preview

By ERICA NAONE

hen I recently decided to start a blog, I had to choose a blogging platform. For two reasons, I chose WordPress. First, I could start my blog in minutes through its free hosting service, paying only if I needed extras such as additional storage space. Second, I was attracted to WordPress's opensource software. If I ever wanted to have

greater control over my how my blog looked and functioned, it would be easy to set up a site at a domain name of my choosing and continue using the software. I'm not the only one

attracted to this no-risk proposition. More than 3.5 million blogs-with hundreds of thousands of posts daily-are hosted on Wordpress.com, which is run by the Web startup Automattic.

Companies offering services like this have pretty much eliminated the need for a blogger to have technical skills. This has made it possible for many more people to maintain blogs, creating a rich online conversational environment (although, of course, one in which anyone looking for quality content has to sort out large numbers of uninteresting or abandoned blogs). In April, Google introduced a preview version

of a tool, App Engine, that could do for the writers of Web applications what Automattic and its ilk have done for bloggers.

Web applications are programs, such as word processors or multiplayer games, that run entirely through a user's Web browser. As such, they change the landscape of software as fundamentally as blogging

> has changed publishing. Web applications allow a programmer to reach any user, regardless of operating system. Small companies (as Salesforce.com was at first) can use them to

take on the giants. Large companies such as Google and Adobe are betting on them to challenge the dominance of Microsoft's Office suite. A Web application, of course, includes software that does whatever the application is intended to do. But it also includes software and hardware that deal with the traffic of people using it. It may require expensive servers and software that divides the application's processing and storage tasks, distributing them efficiently across many machines. Developers have to master what amount to two pretty disparate skills. Though a thorough understanding of infrastructure can help with applica-

tion design, it's not how most application developers want to spend their time. Yet it's important to get the infrastructure right. A sudden increase in Web traffic can kill an unprepared startup, as would-be Google challenger Cuil demonstrated earlier this year, when substantial downtime on launch day soured public opinion. On the other hand, a startup that tries to be too prepared can spend hundreds of thousands of dollars on hardware that winds up going unused.

Google App Engine, which leases infrastructure to companies that need it, enters a field dominated by Amazon.com and its Amazon Web Services. Amazon rents out its excess storage and processing power, and customers-including many startups-pay only for what they use.

Justin Garten, founder of a Web startup called Postful, which converts e-mails into physically mailed letters, says that by using Amazon Web Services, he was able to keep his company much smaller than it would have been otherwise. Garten also likes the ability to pick and choose what services his company gets from Amazon. "Where Amazon has made sense for us, we've used it, and where it hasn't made sense for us, we've built our own server structures," he says.

Google, making characteristic use of its vast resources, is trying to do Amazon one better: App Engine doesn't even start charging money until an application uses more than 500 megabytes of storage or serves more than five million page views a month. The premium version of the service isn't yet available to developers, but Tom Stocky, a Google product manager, says the company hopes that only mature applications will need it. "Once you get to where you hit the quota, you've hopefully started making money," he says.

And yet while App Engine is highly accommodating in its pricing, it is designed not to allow à la carte use of features, as Amazon Web Services does. One cannot, for instance, easily use App Engine solely for storage. Instead, the system comes as a complete package.

Stocky says that App Engine's constraints weren't imposed just to serve Google's business plan—although that's something they certainly do. They also, he says, help applications enjoy the same efficiencies that Google does. Take storage. App Engine uses Google's proprietary database system, which is different from the systems that many developers are familiar with, such as MySQL. Google's system does not allow typical data storage commands that the company says slow applications down when large numbers of users try to call up data.

Software developer Brit Gardner, cofounder of Dallas-based Figaro Interactive, tested App Engine's capabilities by beginning work on a demo application soon after the service came out. Though he didn't know Python, the programming language App Engine requires, he says he was able to build his application in the space of a few days. Gardner says that he sees App Engine as significantly different from Amazon Web Services, in that it's a framework for application development, rather than merely a place to rent processing and storage capacity. He says that his site isn't close to hitting Google's page-view and storage limits, and he doubts that many other sites will be, either, since there are a lot of sites out there and only so many users.

Why would Google give so much away for free? Product manager Pete Koomen says, "We are trying to move the Web forward as a platform. More applications means more users." Indeed, as with blogging, if it's quick and inexpensive for people to set up Web applications, more people are likely to take the plunge, bringing with them the benefits (and troubles) of a rich and crowded field.

However, no matter how quick and easy building Web applications is with App Engine, and no matter how good Google's infrastructure is, the service's lack of openness remains a serious drawback. While Google's representatives say that they want to avoid locking companies into their system, the reality is that as long as important

components such as the database remain proprietary, developers will have limited flexibility. In my case, I don't currently want to *manage* my blog so much as just write it: I just want software that works. Yet it was important to me to reserve the right to move it wherever I want, to add or remove tools, and possibly to learn enough at some point to begin participating in the design of the platform. In its current incarnation, App Engine doesn't give developers analogous options.

While it's possible to get data out of App Engine and move it somewhere else, Stocky says that not all the features that would allow an application to be transferred to some other system have been built yet. In the meantime, a developer who wanted to move away from App Engine would have to find a way to deal with, for example, losing the Google database system and having to move back to one like MySQL. A developer who was taking full advantage of Google's database would have to do a lot of work to make the application function well on a different one. With Google Apps, unlike WordPress, losing the hosting service means losing the platform as well.

Besides, many developers will want to understand how the system underlying their applications works. "We like to know what's going on under the hood," says Gardner. He suspects that at some point, developers will push hard to get a better view.

Nonetheless, developers seem excited about App Engine. It's a brilliant piece of engineering. And for most users, it's hard to beat the price. One of the incredible things about the blogging revolution, however, is that it's led not only to open discussion but to open experimentation with the systems that made it possible. App Engine is certain to lower the barrier to creating a Web startup, and it will bring in many new developers. But if they stick only to what Google's offering, their innovations won't be as far reaching as they might otherwise be.

ERICA NAONE IS A $\mathit{TECHNOLOGY}$ REVIEW ASSISTANT EDITOR.

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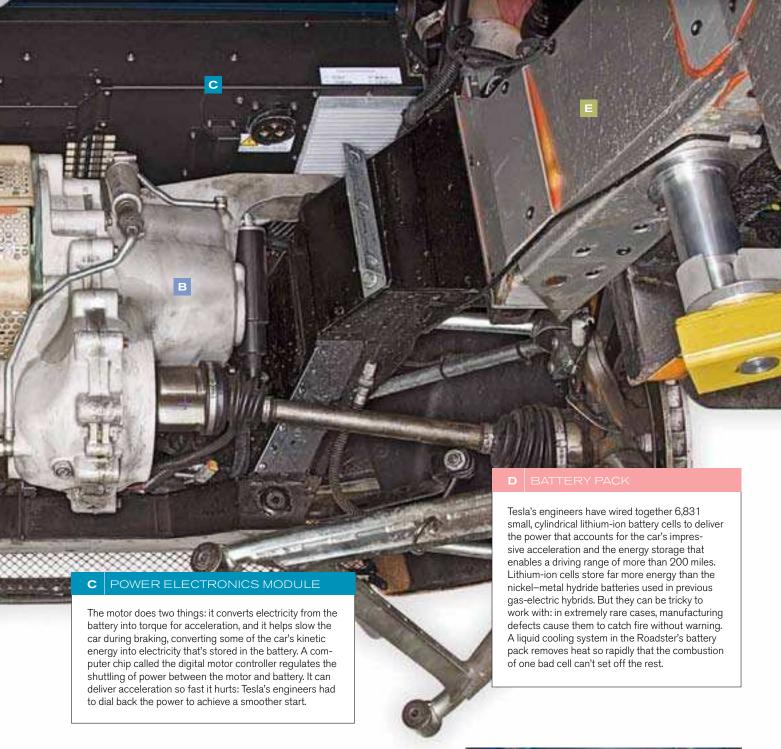
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with its first prototype, the Roadster, introduced in 2006, Tesla Motors ignited interest in electric cars not only as a way to save gas but as a high-performance alternative to some of the fastest sports cars. This year, Tesla started delivering production vehicles, based on the test car shown here. The car sells for \$109,000—but costs only a couple of cents per mile to power.

*See the body on p. 50!



E | BODY AND FRAME

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Watch Tesla CTO JB Straubel demonstrate the Roadster: **technologyreview.com/hack**



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DEMO

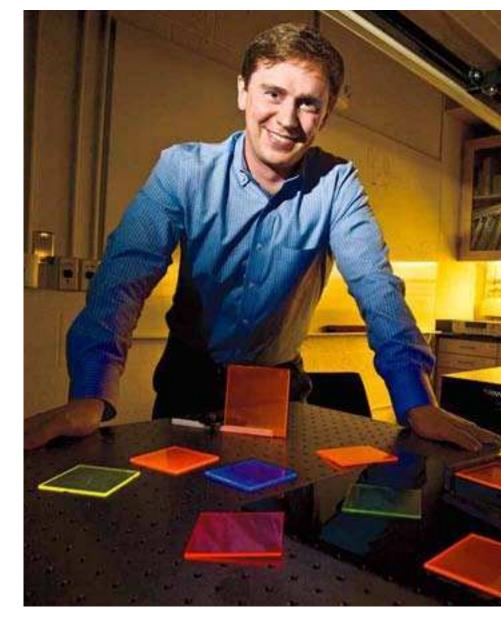
Intensifying the Sun

SUNLIGHT COULD MAKE SOLAR POWER COMPETITIVE WITH FOSSIL FUELS

By KEVIN BULLIS

Tn his darkened lab at MIT, Marc Baldo shines an ultraviolet lamp on a 10centimeter square of glass. He has coated the surfaces of the glass with dyes that glow faintly orange under the light. Yet the uncoated edges of the glass are shining more brightly-four neat, thin strips of luminescent orange.

The sheet of glass is a new kind of solar concentrator, a device that gathers diffuse light and focuses it onto a relatively small solar cell. Solar cells, multilayered electronic devices made of highly refined silicon, are expensive to manufacture, and the bigger they are, the more they cost. Solar concentrators can lower the overall cost of solar power by making it possible to use much smaller cells. But the concentrators are typically made of curved mirrors or lenses, which are bulky and require costly mechanical systems that help them track the sun.



Unlike the mirrors and lenses in conventional solar concentrators, Baldo's glass sheets act as waveguides, channeling light in the same way that fiber-optic cables transmit optical signals over long distances. The dyes coating the surfaces of the glass absorb sunlight; different dyes can be used to absorb different wavelengths of light. Then the dyes reëmit the light into the glass, which channels it to the edges. Solar-cell strips attached to the edges absorb the light and generate electricity. The larger the surface of the glass compared with the thickness of the edges, the more the light is concentrated and, to a point, the less the power costs.

Baldo, an associate professor of electrical engineering, published his findings recently in Science. On their basis, he projects that his solar concentrators could be made big enough for the electricity they help generate to compete with electricity from fossil fuels. Indeed, says Baldo, panels equipped with the concentrators "could be the cheapest solar technology."

SECRET INGREDIENT

The process for making Baldo's solar concentrators begins down the hall in another lab. A postdoctoral researcher, Shalom Goffri, takes several bottles filled with col-







Opposite: Marc Baldo poses with a collection of glass sheets coated with light-emitting organic dyes. The dyes absorb light and reëmit it into the glass, which channels it to the edges of the sheets. Baldo uses the devices to concentrate sunlight, making solar power cheaper.

- **1.** To begin making the solar concentrators, a researcher measures powdered organic dyes into small vials, where they will be mixed with solvents to make ink.
- 2. Next, various inks are mixed together and poured onto a 10-centimeter glass sheet perched on a spin-coating machine. This is done in a sealed box, to protect the researchers from inhaling the solvent.
- **3.** When the glass is spun at 2,000 revolutions per minute, the ink spreads evenly and the solvent evaporates. The concentrator is complete and ready to be connected to solar cells.

orful dye powders from a cabinet and measures the powders into small vials. Some of the dyes were developed for use in car paints; others have been used in organic light-emitting diodes. Both types of dyes can last for years in the sun, a quality essential for solar concentrators. Once he has measured out the powders, Goffri adds a solvent to each to make a liquid ink.

The next steps take place inside a sealed box, so that Goffri doesn't inhale the solvents used to make the dye. He reaches into the box, using thick black gloves mounted in its glass front, and carefully mixes together different inks. Determining the right com-

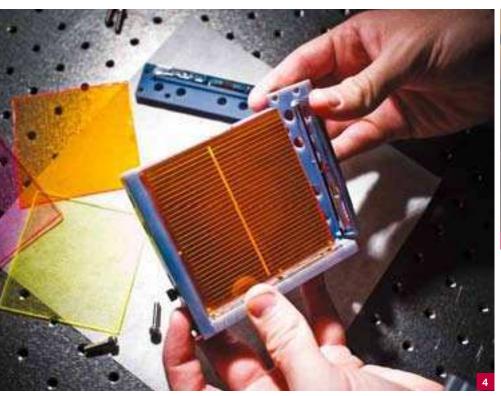
bination of inks solved a fundamental problem that researchers have encountered with this type of solar concentrator. If the glass sheet is coated with a dye that absorbs sunlight in, say, the green-to-blue range of the solar spectrum and emits light of the same wavelength, the emitted light will be quickly reabsorbed by the dye, and little of it will ever reach the edge of the glass. The problem has limited the size of these solar concentrators, since the further the light needs to travel to the edges, the less of the light will make it.

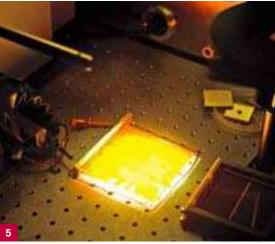
By using certain combinations of dyes interspersed with other light-absorbing

molecules, Baldo makes coatings that absorb one color but emit another. The emitted light is not quickly reabsorbed by the coatings, so more of it reaches the edges of the glass sheet.

The coatings that Goffri is making absorb ultraviolet through green light and emit orange light. Once Goffri has prepared the final mixture, he pours a small amount on a 10-centimeter-wide glass square—the largest that can fit inside a device that spins the glass at 2,000 revolutions per minute to spread the ink evenly. Within a minute or two, the solvent has evaporated and the process is finished. The

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4. Solar cells in the form of thin strips are mounted inside a frame. The cells line up with the edges of the solar concentrator and convert escaping light into electricity. In this prototype, a larger solar cell underneath captures red and infrared light that passes through the glass. 5. Artificial sunlight illuminates a solar concentrator attached to a single thin solar cell for testing.

solar concentrator, with its coating of orange dye, is complete.

THE PROTOTYPE

To generate electricity, Goffri connects the solar concentrator to solar cells. He's making what is called a tandem solar module, a type of solar panel that uses two different kinds of cells to capture more of the energy in sunlight than a single kind could. Different wavelengths of sunlight have different amounts of energy; ultraviolet light has the most and infrared the least. Solar cells are optimized for particular colors. One designed to convert infrared light into electricity, for example, will convert most of the energy in blue light into waste heat. Likewise, red light will pass through a solar cell optimized for high-energy blue light without being absorbed. Ideally, solar cells for different wavelengths would be used in combination to collect the most sunlight, but this approach is often too expensive to be practical.



See how Marc Baldo's solar concentrators work: technologyreview.com/demo

Baldo's concentrators offer an inexpensive way to combine solar cells optimized for different wavelengths of light: different colored coatings can be paired with different types of solar cells in the same device. To make a prototype, Goffri takes a type of solar cell well suited to high-energy colors and glues it to the inside of a plastic frame; then he slides the concentrator into the frame so that its edges line up with the cells. The concentrator captures ultraviolet, blue, and green light and emits orange light that the cells convert into electricity. The lower-energy light, from the red and infrared end of the spectrum, passes through the solar concentrator to the next layer. In the prototype, the next layer is a full-size, conventional silicon solar cell that isn't paired with a solar concentrator.

The prototype, Baldo says, can convert almost twice as much energy from sunlight into electricity as a conventional cell can, provided that the concentrator is roughly 30 centimeters square. This translates to a 30 percent decrease in the cost of solar electricity.

In the future, the cost savings can be much higher, Baldo believes. He doesn't use a concentrator for the infrared light because, so far, no good dyes for capturing those wavelengths exist. But he is confident that such dyes can be developed. When that happens, he will be able to add a second concentrator, for little additional cost, and replace the full-size silicon solar cell with smaller, cheaper cells attached to the concentrators' edges. If the cost of photovoltaics drops over the next several years, as expected, this setup could make solar power about as cheap as electricity from coal, he says.

There's more work to be done in the lab, such as improving the range of colors the concentrators can absorb, which will make it possible to tailor them to specific slices of the spectrum. But Baldo says that it's time to start moving the technology out of the lab and into the market. He and his colleagues have founded a company called Covalent Solar, which is starting to raise money. The company, based in Cambridge, MA, plans to have its first products-probably tandem solar modules-available within three years. TR

KEVIN BULLIS IS TECHNOLOGY REVIEW'S ENERGY

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Career Growth Profile



IRENE POH

Age: 28

Job Title: Senior Business

Analyst

Employer: Procter and Gamble

Programs: MBA, finance and strategy, University of Chicago, 2008; MEng, operations research and industrial engineering, Cornell University, 2002; BS, policy analysis and management, Cornell University, 2001

ike most undergraduates, Irene Poh wasn't sure what she wanted to be "when she grew up." One thing she did know, however, was that she was a "quant at heart." Quantitative subjects such as mathematics and statistics spoke to her. Poh felt strongly that she'd like to use her passion for analysis to make an impact.

Today, at age 28, she is a senior business analyst for Procter and Gamble, providing advisory and consulting services to P&G hair-care marketing teams across North America.

"I work with the various business leaders to provide strategic and tactical recommendations on how to solve some of their highest-priority business problems," Poh explains. "My prior roles at P&G have included global supply-chain consulting, which was more pure operations research and industrial engineering work; I also was a manager at one of P&G's largest warehousing operations in the world."

Not bad for a woman who has yet to stick 30 candles in her birthday cake.

Poh attributes her solid footing in both qualitative and quantitative skills to her bachelor's degree in policy analysis and management and her master's degree in research and industrial engineering from Cornell University.

"Both degrees are about solving difficult programs and influencing decision makers and/ or policy makers at critical moments," says Poh, who says her master's degree also helped her command a higher starting salary when P&G hired her straight out of school.

Three years into her career, however, Poh decided she needed more schooling, and a master's degree in business administration seemed to fit the bill.

To learn more about Irene's decision to continue her education and how it helped her move up the corporate ladder, go to www.technologyreview.com/careerresources/.

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FROM THE LABS

NANOTECHNOLOGY

A MUCH-NEEDED WAY TO EVALUATE NANO-MATERIALS' SAFETY

SOURCE: "PERTURBATIONAL PROFILING OF NANOMATERIAL **BIOLOGIC ACTIVITY**

Stanley Y. Shaw et al. Proceedings of the National Academy of Sciences 105: 7387-7392

Results: Researchers have developed a way to evaluate the safety of nanoparticles by quickly comparing them to nanoparticles already tested for toxicity. They determined the effects of different doses of nanoparticles on a variety of cell types in culture. Then they performed tests in mice, showing that their tests on cells could predict which nanoparticles would have effects in animals similar to those of previously screened nanoparticles.

Why it matters: Hundreds of products containing nanomaterials are already on the market, and more are under development. Few if any of the materials have been thoroughly tested. The new assay is faster and cheaper than testing in animals but appears to give a good approximation

of the results; it represents an important step toward speeding up the process of evaluating new nanomaterials. The approach could help researchers choose between similar nanoparticles on the basis of potential safety risks.

Methods: The researchers tested 50 nanoparticles, most of which are being developed for medical imaging, in the four cell types that they are most likely to encounter in the body. Each nanoparticle was tested at four different concentrations in mouse immune cells, human liver cells, and two types of human blood-vessel cells. Automated systems collected data on cell death, metabolic changes, and other signs of toxicity.

Next steps: The experiment, which focused mostly on iron-containing nanoparticles and tiny semiconductor particles called quantum dots, now needs to be extended to other nanomaterials. The assay works well for nanoparticles entering the body intravenously, but to test the properties of nanomaterials that might enter in other ways, including inhalation, future assays will need to use different cell types, such as lung cells.

Acoustic

MATERIALS THAT **DEFLECT SOUND WAVES**

SOURCE: "ACOUSTIC CLOAKING IN TWO DIMENSIONS: A FEASIBLE APPROACH"

Daniel Torrent and José Sánchez-

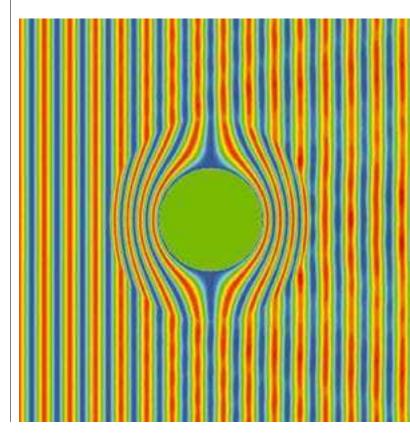
New Journal of Physics 10: 63015-

Results: Designs have been drawn up for a material that could lead to the first acoustic cloaking device. Computer models suggest that alternating layers of two types of patterned, elastic rods, called sonic crystals, would direct sound waves around an object so that they re-formed on the other side with no distortion,

as if the sound waves had never encountered the object.

Why it matters: The cloak could make ships invisible to sonar and improve the acoustics of concert halls by allowing sound to pass around load-bearing columns. Buildings covered in the material would be shielded from street noise. Other researchers have designed and built materials that can cloak objects from microwaves, but they divert only particular wavelengths. The new research predicts that an acoustic cloak would shield objects from a broad

Sound waves, moving from left to right, encounter an object surrounded by an "acoustic cloak" that causes the waves to re-form as if the object weren't there.



spectrum of sounds, from high pitches to low.

Methods: The researchers developed computer models based on previous theoretical work and used them to simulate the movement of sound waves around acoustic cloaks with varying numbers of layers. The models showed that sound waves flow best around materials made of 200 layers of composite sonic crystals.

Next steps: The designed material would work only in two dimensions-with sound waves traveling in a plane. The researchers will extend their theoretical work, developing new designs for materials that work in three dimensions, and then build and test them.

BIOTECHNOLOGY

Genetically Prescribed Vitamins

NEWLY DISCOVERED GENETIC VARIATIONS COULD PREDICT WHO NEEDS MORE FOLIC ACID

SOURCE: "THE PREVALENCE OF FOLATE-REMEDIAL MTHFR ENZYME **VARIANTS IN HUMANS"**

Nick Marini et al. Proceedings of the National Academy of Sciences 105: 8055-8060

Results: Scientists at the University of California, Berkeley, identified several new variations in the gene for methylenetetrahydrofolate reductase (MTHFR), an enzyme that converts the B vitamin folate (called folic acid in supplements) from



one form into another. They found that some variants of the enzyme need more folate to work effectively, a finding that could have implications for human nutrition.

Why it matters: Scientists hope that this type of research will eventually pave the way for individually tailored doses of vitamins. In particular, the work may help suggest who needs to take more folic acid to prevent ailments such as birth defects and possibly heart disease, which have been linked to malfunction of the MTHFR enzyme.

Methods: Researchers sequenced the MTHFR gene in 564 people of different ethnicities. Then they added the human gene sequences to yeast cells, which were engineered so that their growth rate depended on how well the enzyme was working. By feeding the yeast varying

This MRI of a mouse brain clearly shows a dark circle (arrow) of magnetic cells. The cells, genetically engineered to produce magnetic particles and then injected into the brain, could provide a new approach to imaging.

amounts of folate, the scientists could determine which of the genetic variants needed more of the vitamin to function properly.

Next steps: An ongoing human study performed in collaboration with the Children's Hospital Oakland Research Institute and the Joint Genome Institute in Walnut Creek, CA, should provide more data on the enzyme's role in birth defects. Scientists will sequence the gene in 250 normal children and 250 children with neuraltube defects to see whether the poorly functioning variants appear more often in the latter.

Magnetic Genes

GENETICALLY ENGINEERED CELLS MAKE THEIR OWN NANO MAGNETS. PROVIDING CLEAR MRI IMAGES

SOURCE: "MAGA IS SUFFICIENT FOR PRODUCING MAGNETIC NANOPARTICIES IN MAMMALIAN CELLS, MAKING IT AN MRI REPORTER"

Xiaoping P. Hu and Anthony W. S.

Magnetic Resonance in Medicine 59: 1225-1231

Results: Scientists genetically engineered mammalian cells to produce magnetic particles three to five nanometers in diameter. The particles can be detected with magnetic resonance imaging (MRI), which could give scientists a novel way to track cells in the body.

Why it matters: Scientists typically use fluorescent markers to track specific cell types. But fluorescent signals can't travel very far through animal tissue, so the approach is of limited use in live studies. Cellular labels detectable with MRI, which can see deep into the body, could allow scientists to observe a range of biological processes as they unfold in live animals.

Methods: From a ponddwelling bacterium, scientists isolated a gene for producing magnetic particles, which the bacterium uses like a compass. They inserted the gene into human cells and injected the cells into the brains of live mice. The mouse cells began to produce their own magnetic particles and could be seen clearly with MRI.

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ers will further assess how the nanoparticles could be used with MRI by better characterizing them and measuring their effect on cells-determining, for example, whether they are toxic or whether they alter cellular functions in living animals.

Next steps: The research-

INFORMATION TECHNOLOGY

Low-Power

AN EFF<mark>I</mark>CIENT NEW CHIP COULD BE USED FOR IMPLANTABLE MEDICAL SENSORS

SOURCE: "THE PHOENIX PROCES-SOR: A 30PW PLATFORM FOR SENSOR APPLICATIONS"

Mingoo Seok et al. IEEE Symposium on VLSI Circuits, June

Results: Researchers at the University of Michigan have designed a chip less than one

millimeter square that uses about a 10th as much energy as the most energy-efficient chips on the market.

Why it matters: The chip could be a boon to sensor design. Its small size-along with the energy savings it provides, which reduce the size of the battery needed-makes it feasible to build sensors that could be implanted under the skin to gauge glucose levels in subcutaneous fluid, or in contact lenses to monitor pressure on the eye.

Methods: Since sensor chips are inactive most of the time, the researchers focused on reducing the amount of energy wasted when the chip is in sleep mode. They redesigned the chip to use less memory (a big source of energy leakage), in part by incorporating hardware for data compression. Next, they reduced the small amounts

of power that most transistors leak even when turned off, opting for slightly larger transistors that leak less. They also added special transistors that completely shut off the power supply to the processing transistors when they're not in use.

Next Steps: The researchers will add a battery to the chip and develop a way to wirelessly download data from it.

Denying Attacks

STOPS INTELLIGENT DENIAL-OF-SERVICE **ATTACKS**

SOURCE: "MITIGATING APPLICATION-LEVEL DENIAL OF SERVICE ATTACKS ON WEB SERVERS: A CLIENT-TRANSPARENT APPROACH"

Mudhakar Srivatsa et al ACM Transactions on the Web, July 2008: 15

Results: Researchers at IBM's T. J. Watson Research Center and Georgia Tech have developed new security software that minimizes the effects of a type of attack that ties up websites with automated requests, preventing people from using them. The software is tailored to websites that host applications, such as wordprocessing and interactiveshopping programs.

Why it matters: Denial-ofservice attacks can shut down websites, potentially costing millions in revenue. They're particularly difficult to pre-

The tiny chip at the center of this penny could be used to control biomedical implants.

vent on websites that host applications, since the automated requests can look very similar to requests from real website users. Distinguishing legitimate users from attackers usually requires cumbersome and inconvenient procedures for logging in to a site. The new software avoids this requirement.

Methods: The researchers wrote algorithms for two filtering systems that prevent attacks. The first limits the total number of requests to the website; the second gives priority to certain users on the basis of what they do on the site. For example, a user who frequently hits the "buy" button will be given higher priority, while users making a quick succession of demanding requests-for example, to download many large image files-will be given a low priority. Would-be attackers would tend to make more requests that use up a lot of bandwidth, memory, or processing power but would not perform valuable actions such as making purchases, so they would be flagged; their access to the site would be reduced and eventually cut off.

Next steps: To use the system, programmers must categorize the activities of a website's users and assign values to each activity. The researchers' system currently provides an interface that allows programmers to do this. They plan to improve the interface, developing tools to help programmers make the necessary judgments. TR



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Having the President's Ear

A LOOK BACK AT A TIME WHEN SCIENCE HELD SWAY By MATT MAHONEY

n January 1974, TR published remarks made on October 4, 1973, when MIT convened the six scientists who'd chaired the President's Science Advisory Committee (PSAC) to discuss the subject of "Science Advice for the White House." It was a remembrance service of sorts, as President Nixon had recently abolished the committee. What role, if any, a science advisor would have in future administrations was an open question.

What a difference 16 years had made. On another October 4, this one in 1957, the Soviet Union had, with the launch of Sputnik, gotten the jump in the space race; Americans demanded to know how the president planned to catch up. Eisenhower quickly established PSAC, with James R. Killian, then the president of MIT, at its head. The president explained that the move would "make it possible for me, personally, whenever there appears to be any unnecessary delay in our development system, to act promptly and decisively."

Killian and the 18 scientists he recruited to form PSAC found an ideal patron in Eisenhower, and the committee played a key role in developing national-security strategy, establishing NASA, and reforming the national science curriculum. But the relationship between the president and his science advisors (Eisenhower referred to them as "my scientists") went deeper than any particular policy discussions, Killian recalled:

View a time line of science advisors from the Truman administration on: technologyreview.com/advisors

The importance of PSAC goes far beyond the specific outcomes of its studies and recommendations because of the relationships of confidence and free discussion that PSAC enjoyed with the President and the President's associates. ... These meetings, in which there was free-for-all discussion, were memorable events for PSAC itself. They made it



THE AGE OF INFLUENCE James Killian (center) has a laugh with President Eisenhower (left), Isidor Rabi (right), and fellow scientists.

possible for a group of scientists to come to understand the President's problems, views, and goals, and to learn how to make themselves useful in the light of this understanding. So it was that the Committee found many ways to express its belief in the values of a free society not only for the advancement of science but for the good of mankind.

Later presidents would prove less responsive to a committee whose recommendations were sometimes at odds with administration policy. President Kennedy embraced the advisory system he inherited from Eisenhower, but conflict between the Johnson administration and PSAC over such issues as the

antiballistic-missile program, supersonic transport, and the conduct of the Vietnam War caused the committee's influence to wane. Donald F. Hornig, science advisor during this period, explained:

There is nothing sadder than an adviser whose advice isn't wanted. During World War II and at the time of Sputnik, there was a clear identity of interest between the scientific community and the President. The President knew he needed advice, and the country knew he needed advice; and under Killian a heroic role was played. As time went on, quite aside from the building up of scientific expertise in the Department of Defense, attentions turned to other things; the most urgent political items were no longer quite so closely allied with the things PSAC was interested in. And in fighting its own personal battles, PSAC came to be regarded, rightly or wrongly, as having its own political positions.

Goodwill eroded to the point that Nixon felt the committee could best serve his interests by ceasing to exist. A science advisory committee, in modified form, was restored under President Ford, and every president since has at least given the appearance of having expert scientific advice at his command, but the influence PSAC wielded at its height has never been equaled. It was a unique set of historical circumstances that established the "identity of interest" Hornig described. And it was also a special collection of people, Killian recalled, who were able to serve two such demanding masters-science and the president-simultaneously:

This group of science advisers had a deep sense of responsibility to science, along with an unshakable faith in its importance both to the individual and to the nation. They loved science and wanted others to share their enthusiasm for it and to discover its inner power to make men and women a little more creative, a little more civilized, and a little more humane. TR

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